MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXVI. FEBRUARY 9, 1906. No. 4

ANNUAL GENERAL MEETING.

Mr. W. H. MAW, PRESIDENT, in the Chair.

The Report of the Auditors of the Treasurer's accounts for the year 1905 was read; see p. 154.

The Address was delivered by the President, after which the Gold Medal was handed to His Excellency the American Ambassador for transmission to Professor W. W. Campbell, to whom the Medal had been awarded for his spectroscopic researches, which have greatly increased our knowledge of Stellar Motions (see pp. 245 to 261).

The Annual Report of the Council was partly read; see pp. 151 to 244.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 261.

The thanks of the Meeting were given to the retiring Officers, and also to the Auditors of the Treasurer's Accounts and to the Scrutineers of the ballot.

Robert Courtenay, B.A. (T.C.D.), 34 Wilmount Street, Woolwich ;

Lieut. Chetwode G. G. Crawley, R.M. Artillery, B.A. (T.C.D.), H.M.S. " Vernon," Portsmouth ; and

John Milne Gardiner Shaw, M.Inst. Naval Architects, F.R.Met.Soc., c/o John Swire & Sons, 8 Billiter Square, E.C.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Rev. Walter Briscombe, Wesleyan Minister, Hillam Royd, Abbey Park Road, Grimsby (proposed by R. Wilding) ;

Arthur Stanley Eddington, B.A., Trinity College, Cambridge (proposed by E. T. Whittaker) ; and

Dr. Edalgi Manekji Modi, F.C.S., F.Z.S., F.R.M.S., &c., Manufacturing and Consulting Chemist, Sleater Road, Bombay, India (proposed by J. D. Bharda).

Report of the Council to the Eighty-sixth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron and Hon. Members	Grand Total
1904 December 31	262	382	644	49	3	696
Since elected	+ 3	+ 42	...	+ 3	...	...
Deceased	− 7	− 10	...	− 3	...	...
Resigned	...	− 14	...	...	...	...
Removals	+ 1	− 1	...	...	...	...
Expelled	...	− 1	...	...	...	...
1905 December 30	259	398	657	49	3	709

Major Hills' Account as Treasurer of the Royal

RECEIVED.

	£	s.	d.	£	s.	d.
Balances, 1904 December 31 :—						
At Bankers', as per Pass-book	252	7	5			
In hand of Assistant Secretary on Account of Turnor and Horrox Fund	9	17	9			
				262	5	2
Dividends on £1,250 Metropolitan 3-per-cent. Stock	35	12	8			
Dividends on £932 19 0 Metropolitan 2½-per-cent. Stock	22	3	4			
Dividends on £3,400 East Indian Railway 3-per-cent. Debenture Stock	96	18	0			
Dividends on £3,200 London and North-Western Railway 3-per-cent. Debenture Stock	91	4	0			
Dividends on £4,000 Midland Railway 2½-per-cent. Debenture Stock	95	0	0			
Dividends on £500 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock	14	5	0			
Dividends on £1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock	53	0	2			
Dividends on £1,650 Commercial Gas Co. 3-per-cent. Debenture Stock	47	0	6			
Half-Year's Dividend on Investment of £1,600 of the McClean Bequest in £1,484 17*s.* 5*d.* Swansea Corporation 3½-per-cent. Stock ...	24	13	9			
				479	17	5
Received on account of Subscriptions :—						
Arrears	170	2	0			
Annual Contributions for 1905	577	10	0			
„ „ „ 1906 in advance ...	8	8	0			
Admission Fees	98	14	0			
First Contributions	72	9	0			
				927	3	0
Composition Fees				99	15	0
Sales of Publications, &c. :—						
At Williams & Norgate's, 1904	33	18	6			
At Society's Rooms, 1905	52	14	6			
Sales of Photographs	32	9	0			
				119	2	0
Income Tax refunded by Commissioners of Inland Revenue				23	12	1
Bequest of the late Mr. Frank McClean				2,000	0	0
Loan from Bankers				400	0	0
Cheques Outstanding				16	19	6
				£4,328	14	2

Audited and found correct, 1906 Jan. 9 :
WALTER W. BRYANT.
F. W. LEVANDER.
WM. SHACKLETON.

Astronomical Society, from 1905 *January* 1 *to December* 30.

PAID.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
,, ,, For editing Society's Publications	50	0	0			
Clerk's Salary	75	0	0			
				375	0	0
House Duty	2	12	6			
Fire Insurance	9	9	6			
				12	2	0
Printing *Memoirs*, vol. lv., &c. (Spottiswoode & Co.)	283	6	0			
,, ,, vol. lvii. pts. 1, 2 ,, ,,	183	14	6			
Printing, plates, &c., *Monthly Notices* ,, ,,	597	19	3			
Printing, plates, &c., Appendix to *Monthly Notices* (Harrison & Sons)	5	11	0			
Printing, List of Fellows and Miscellaneous (Spottiswoode & Co.)	19	16	6			
Photo-plates for *Monthly Notices* (A. E. Dent & Co.)	19	13	7			
				1,110	0	10
Computation of Ephemerides in *Monthly Notices* ...				15	0	0
Turnor and Horrox Fund, purchase of books for Library	21	3	10			
Binding books in Library	32	9	6			
Cabinet for Card Catalogue in Library	5	10	0			
				59	3	4
Reproduction of Photographs, Hinton & Co. ...				34	2	8
Cataloguing astronomical literature for the International Catalogue of Scientific Literature ...				30	0	0
Expenses of Meetings	21	0	0			
Lantern Expenses	7	13	6			
Time Signal: Rental of Wire	5	0	0			
				33	13	6
Postage and Telegrams	94	8	7			
Carriage of Parcels, &c.	5	19	4			
Stationery (Spottiswoode & Co.)	5	17	0			
Sundry Stationery and Office Expenses	4	13	5			
				110	18	4
Repairs to Coelostat...				1	0	0
Decorations and Electric Light Installation, &c. (Geo. Trollope & Sons)	370	12	6			
Re-covering Seats in Meeting Room (Maple & Co.)	63	16	8			
Restoring Oil Paintings (F. Haines & Sons) ...	11	15	0			
				446	4	2
House Expenses: Allowance, and Sundry Expenses	62	1	2			
British Vacuum Cleaning Co. (cleaning books in Library)	13	4	0			
Coal and Gas	41	0	6			
Electric Light Expenses	14	0	6			
Sundry Fittings and Repairs	10	15	6			
Sundries	3	14	11			
				144	16	7
Jackson-Gwilt Gift to Mr. John Tebbutt				25	0	0
Purchase of £1,484 17*s.* 5*d.* Swansea Corporation 3½-per-cent. Stock (investment of part of the McClean Bequest)				1,600	0	0
Cheque Book and Deductions on Cheques... ...				0	10	8
Repayment to Assistant Secretary of amount due 1904 Dec. 31 on Petty Cash Account... ...				9	10	0
Interest on Loan from Bankers				0	19	9
Balances, 1905 December 30:—						
At Bankers', as per Pass-book	299	0	2			
Cheques not Credited till 1906	7	18	5			
In hand of Assistant Secretary on Account of Turnor and Horrox Fund...	4	13	11			
In hand of Assistant Secretary on Petty Cash Account	8	19	10			
				320	12	4
				£4,328	14	2

Report of the Auditors.

We have examined the Treasurer's accounts of receipts and expenditure for the year 1905, and have found and certified the same to be correct. The cash in hand on December 31, 1905, including the balance at the bankers', &c., amounted to £320 12*s.* 4*d.*

We regret to find that an overdraft of £400 at the bank has been found necessary; this, however, appears to be due to the expense of decorating the Society's premises and to a great increase in the bill for printing.

The funded property of the Society has been increased by the purchase of £1,484 17*s.* 5*d.* Swansea Corporation 3½-per-cent. Stock, being the investment of £1,600 of the McClean Bequest of £2,000.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition, with the exception of some of the instruments in the basement; in regard to which we strongly urge the desirability of taking steps to reduce their number by eliminating such instruments, or parts of instruments, as are no longer of any practical value or historical interest.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(*Signed*) WALTER W. BRYANT.
F. W. LEVANDER.
WM. SHACKLETON.

Bequests to the General Funds of the Society.

The Carrington Bequest (1876).—A sum of £2,000 Consols. Sold in 1899 and the proceeds invested in the purchase of £1,881 14*s.* London and North-Western Railway 3-per-cent. Debenture Stock.

The McClean Bequest (1905).—A sum of £2,000. £1,600 of this sum invested in the purchase of £1,484 17*s.* 5*d.* Swansea Corporation 3½-per-cent. Stock.

Trust Funds.

The Turnor Fund: A sum of £464 18*s*. East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £103 6*s*. East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £334 10*s*. 9*d*. East Indian Railway 3-per-cent. Debenture Stock; the interest to be given by the Council to the widow or orphan of any deceased Fellow of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £309 18*s*. 6*d*. East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1906 *January* 1.

	£	*s*.	*d*.	£	*s*.	*d*.
Balances, 1905 December 31:—						
At Bankers', as per Pass-book	299	0	2			
Cheques not credited till 1906	7	18	5			
In hand of Assistant Secretary:—						
Turnor and Horrox Fund	4	13	11			
Petty Cash Account	8	19	10			
	320	12	4			
Less cheques outstanding	16	19	6			
				303	12	10
Due on account of Subscriptions:—						
1 Contribution of 5 years' standing	10	10	0			
6 Contributions of 4 ,, ...	50	8	0			
13 ,, 3 ,, ...	81	18	0			
27 ,, 2 ,, ...	113	8	0			
57 ,, 1 year's standing	119	14	0			
	375	18	0			
Less paid in advance	8	8	0			
				367	10	0
				671	2	10
Less loan from Bankers				400	0	0
				271	2	10
Due for Photographs sold				0	4	0
Due from Messrs. Williams & Norgate for sales of Publications, 1905				11	16	0

£3,400 East Indian Railway 3-per-cent. Debenture Stock, including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (*née* Gwilt) Fund.

£3,200 London and North-Western Railway 3-per-cent. Debenture Stock (including the Carrington Bequest).

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£500 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

£1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£1,650 Commercial Gas Company 3-per-cent. Debenture Stock.

1,250 Metropolitan 3-per-cent. Stock.

£932 19*s.* 0*d.* Metropolitan 2½-per-cent. Stock.

£1,484 17*s.* 5*d.* Swansea Corporation 3½-per-cent Stock (being £1,600 of the McClean Bequest of £2,000).

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

One Gold Medal.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows :—

R.A.S. Ref. No.	Subject.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*	Isaac Roberts
5	Nebula M 74 *Piscium* (N.G.C. 628)	Isaac Roberts
6	Great Nebula in *Orion*	Isaac Roberts
7	Milky Way near M 11	E. E. Barnard
8	Milky Way near Cluster in *Perseus*	E. E. Barnard
9	Comet *c* 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet *a* 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about *η Argûs*	David Gill
12	Portion of Moon (Hyginus-Albategnius)	Loewy and Puiseux
13	Comet *c* 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet *c* 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet *c* 1893 IV. (Brooks), 1893 November 10	E. E. Barnard

R.A.S. Ref. No.	Subject.	Photographed by
16	Comet *a* 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet *f* 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet *a* 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	Loewy and Puiseux
20	Nebula in *Andromeda*	Isaac Roberts
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis* (N.G.C. 6205)	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age 7^d 3^h)	Lick Observatory
26	The Moon (Age 12^d $6\frac{1}{2}^h$)	Lick Observatory
27	The Moon (Age 16^d 18^h)	Lick Observatory
28	The Moon (Age 23^d 8^h)	Lick Observatory
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of Maginus)	Loewy and Puiseux
32	The Moon (Age 14^d 1^h)	Lick Observatory
33	Portion of Moon (Ptolemæus, &c.)	Lick Observatory
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ* (N.G.C. 6779)	
42	Nebulæ M 81, 82 *Ursæ Majoris* (N.G.C. 3031, 3034)	
43	Cluster M 56 *Lyræ* (enlarged) (N.G.C. 6779)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney

R.A.S. Ref. No.	Subject.	Photographed by
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*	W. E. Wilson
57	Dumb-bell Nebula, *Vulpecula* (N.G.C. 6853)	W. E. Wilson
58	Spiral Nebula, *Canes Venatici* (N.G.C. 5194)	W. E. Wilson
59	Ditto (enlarged) (N.G.C. 5194)	W. E. Wilson
60	Annular Nebula, *Lyra* (N.G.C. 6720)	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*	Roy. Obs., Greenwich
67	Spectrum of Sun's limb, 1898 January 22	E. H. Hills
68	Annular Nebula, *Lyra* (N.G.C. 6720)	Lick Observatory
69	Dumb-bell Nebula, *Vulpecula* (N.G.C. 6853)	Lick Observatory
70	Spiral Nebula, *Canes Venatici* (N.G.C. 5194–5)	Lick Observatory
71	Spiral Nebula, *Ursa Major* (N.G.C. 5457)	Lick Observatory
72	Trifid Nebula, *Sagittarius* (N.G.C. 6514)	Lick Observatory
73	Great Nebula in *Orion*	Lick Observatory
74	Cluster M 13 *Herculis* (N.G.C. 6205)	Lick Observatory
75	Solar Surface with Faculæ	G. E. Hale
76	Faculæ and Prominences	G. E. Hale
77	Total Solar Eclipse, 1898 Jan. 22 ($\frac{2}{3}$ sec.)	W. H. M. Christie
78	Nebula H V. 14 *Cygni* (N.G.C. 6992)	W. E. Wilson
79	Portion of Moon (Theophilus, &c.)	Yerkes Observatory
80	Total Solar Eclipse, 1900 May 28 (30 sec.)	E. E. Barnard
81	Comet 1901 I., 1901 May 4	Roy. Obs., Cape of G. H.
82	Comet 1901 I., 1901 May 6	Roy. Obs., Cape of G. H.
83	Comet 1901 I., 1901 May 9	Perth Obs., W. Australia
84	Solar Surface with Faculæ	H. Deslandres
85	Solar Prominences	H. Deslandres
86	Nebula about Nova *Persei*, 1901 September 20	G. W. Ritchey
87	Nebula about Nova *Persei*, 1901 November 13	G. W. Ritchey
88	Total Solar Eclipse, 1901 May 18 (10 sec.)	F. W. Dyson
89	Total Solar Eclipse, 1901 May 18 (40 sec.)	F. W. Dyson
90	Comet *b* 1902 III. (Perrine), 1902 Sept. 29	Roy. Obs., Greenwich
91	Portion of Moon (Mare Serenitatis, &c.)	Yerkes Observatory
92	Portion of Moon (Rough Crater Region, Mare Nubium)	Yerkes Observatory

R.A.S. Ref. No.	Subject.	Photographed by
93	Portion of Moon (Tycho, Theophilus, &c.)	Yerkes Observatory
94	Portion of Moon (Bullialdus to Copernicus)	Yerkes Observatory
95	Portion of Moon (Copernicus)	Yerkes Observatory
96	Great Nebula in *Orion*	Yerkes Observatory
97	Great Nebula in *Orion* (Central portion)	Yerkes Observatory
98	Nebula in *Andromeda*	Yerkes Observatory
99	Nebula in *Cygnus* (N.G.C. 6960)	Yerkes Observatory
100	Nebula in *Cygnus* (N.G.C. 6992)	Yerkes Observatory
101	Cluster M 13 *Herculis* (N.G.C. 6205)	Yerkes Observatory
102	Cluster M 15 *Pegasi* (N.G.C. 7078)	Yerkes Observatory
103	Solar Surface with Faculæ	Yerkes Observatory
104	The Moon, 1900 April 5	P. Puiseux
105	The Moon, 1902 November 13	P. Puiseux
106	The Moon, 1903 February 6	P. Puiseux
107	The Moon, 1903 September 12	P. Puiseux
108	Nebulosity about 15 *Monocerotis*	E. E. Barnard
109	Milky Way about β *Cygni*	E. E. Barnard
110	Nebulosity near α *Cygni*	E. E. Barnard
111	Milky Way near χ *Cygni*	E. E. Barnard
112	Star cloud in *Sagittarius*	E. E. Barnard
113	Milky Way in *Cepheus*	E E. Barnard
114	Milky Way about M 8	E. E. Barnard
115	Milky Way about θ *Ophiuchi*	E. E. Barnard
116	Milky Way near N.G.C. 6475	E. E. Barnard
117	Great Nebula near ρ *Ophiuchi*	E. E. Barnard
118	Milky Way about 58 *Ophiuchi*	E. E. Barnard
119	Milky Way near *Omega* nebula	E. E. Barnard
120	Star cloud in *Sagittarius*	E. E. Barnard
121	Nebula about ν *Scorpii*	E. E. Barnard
122	Sun, 1905 January 30	Roy. Obs., Greenwich
123	Sun-spot, 1905 January 30	Roy. Obs., Greenwich
124	Sun, 1905 January 31	Roy. Obs., Greenwich
125	Sun-spot, 1905 January 31	Roy. Obs., Greenwich
126	Sun, 1905 February 2	Roy. Obs., Greenwich
127	Sun-spot, 1905 February 2	Roy. Obs., Greenwich
128	Sun, 1905 February 3	Roy. Obs., Greenwich
129	Sun-spot, 1905 February 3	Roy. Obs., Greenwich
130	Sun, 1905 February 5	Roy. Obs., Greenwich
131	Sun-spot, 1905 February 5	Roy. Obs., Greenwich

R.A.S. Ref. No.	Subject.	Photographed by
132	Sun, 1905 February 8	Roy. Obs., Greenwich
133	Sun-spot, 1905 February 8	Roy. Obs., Greenwich
134	Nebula near ψ *Eridani*, 1905 January 8	Max Wolf
135	Nebula M 33 *Trianguli*	Isaac Roberts
136	Nebula in *Perseus* (N.G.C. 1499)	Isaac Roberts
137	Nebula in *Monoceros* (N.G.C. 2237–9)	Isaac Roberts
138	Nebula H V. 24 *Comæ*	Isaac Roberts
139	Nebulæ H V. 42, &c., *Comæ*	Isaac Roberts
140	Nebulæ H V. 37 *Cygni*	Isaac Roberts
141	Nebula Index Cat. 405 *Persei*	Isaac Roberts
142	Cluster H VI. 33–4 *Persei*	Isaac Roberts
143	Cluster H VI. 30 *Cassiopeiæ*	Isaac Roberts
144	Eclipse, 1905 August 30 (5 sec.)	W. H. M. Christie
145	Eclipse, 1905 August 30 (20 sec.)	W. H. M. Christie
146	Eclipse, 1905 August 30 (7 sec.)	W. H. M. Christie
147	Eclipse, 1905 August 30 (20 sec.)	W. H. M. Christie
148	Eclipse, 1905 (Portion) August 30	W. H. M. Christie

Nos. 44–55 and Nos. 64, 65 and 147 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches ; also unmounted, and as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, $6\frac{1}{4}$ inches square.

Price of prints, mounted, 1*s.* 6*d.* each, unmounted, 1*s.* each ; lantern slides, 1*s.* each ; packing and postage extra.

Transparencies, $6\frac{1}{4}$ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required, and whether mounted or unmounted.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Professor W. W. Campbell for his spectroscopic researches, which have greatly increased our knowledge of Stellar motions. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

During the past year vol. lv. of the *Monthly Notices*, with two Appendices reprinted from the *Proceedings of the Royal Society*, has been published.

In consequence of the increase in the size of the page of the *Proceedings* the reprinting of these Appendices is now discontinued. The Reports of the Joint Eclipse Meeting of the Royal and Royal Astronomical Societies on 1905 October 19 will, however, be issued to the Fellows as a separate publication.

The Council have decided that each paper in the *Memoirs* shall be printed and circulated separately, and the following have been issued during the past year :—

Vol. lvii. pt. 1. S. A. Saunder, The Determination of Selenographic Positions and the Measurement of Lunar Photographs. Third paper : Results of the Measurement of Four Paris Negatives.

Vol. lvii. pt. 2. E. W. Brown, Theory of the Motion of the Moon, containing a New Calculation of the Expressions for the Co-ordinates of the Moon in the Terms of the Time. Part IV., Chapters VII.–IX.

Vol. lvi. of the *Memoirs*, containing Mr. Lewis's Memoir on the measures of the double-stars in Struve's *Mensuræ Micrometricæ*, is in the press, and will be published in the course of the present year.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Thomas Michael Almond.
Walter Ernest Besley.
George Cox Bompas.
Ralph Copeland.
Edward Crofton.†
Edward Crossley.*
John Dansken.
Rev. Adam Storey Farrar.
Lord Grimthorpe.
Rev. Timothy Harley.†
Charles Horsley.*
Rev. Samuel J. Johnson.
Lieut.-Col. Henry S. G. S. Knight.†
Thomas Edward Knightley.
George Richard Stevens.
Rev. William R. M. Waugh.
Sir W. J. Lloyd Wharton.

Associates :—Paul Henry.*
Otto Struve.
Pietro Tacchini.

Obituary notices are also given of E. H. R. Coleman and Charles Jasper Joly, who died in January 1906.

Walter Ernest Besley was born at Tiverton, North Devon, in 1877, the elder son of Walter Besley. He was educated on the classical side at Heavitree College, near Exeter, and, for one year, in London. In 1896 he obtained by examination a Second Division Civil Service clerkship, and was appointed to the office of the Local Government Board in Whitehall, where, until his death, his work lay, under its former and present Superintendents, the late Sir R. Thorne and Mr. W. H. Power, in the Public Health Department.

In 1895, when as yet only 17 years of age, he commenced to observe meteors and the brighter variable stars, communicating

* Obituary in *Annual Report*, 1905.
† Death not reported till 1905.

his results to the *English Mechanic*. In 1898, on the death of his father, Mrs. Besley came to live with her sons in London, and a house was taken adjoining the north side of Clapham Common; here the greater part of his astronomical work was accomplished. In 1900 he was appointed Director of the Meteor Section of the British Astronomical Association, having joined the Association in 1896, and having then applied himself with good effect to variable star and meteor observations; and he held this office until in April 1905 he was compelled by increasing ill-health to resign it.

Mr. Besley was elected a Fellow of the Royal Astronomical Society in January 1902, and was at first an occasional attendant at its meetings, but in the last two years, chiefly on account of illness, he was unable to be present. In spite of attempts to recruit his health by visits to his native Devonshire—where his time was chiefly taken up in editing meteoric observations—his condition gradually became more serious, and on the 29th of June 1905, at the early age of 27 years, this devoted and able observer passed away.

[The Council are indebted to Professor A. S. Herschel for the above particulars.]

George Cox Bompas was born on the 18th of April 1827, being the second son of the late Serjeant Bompas. He was educated privately, and was admitted as a solicitor in 1850, continuing to practise till 1903. He married in 1860 Mary Anne Scott Buckland, daughter of the Rev. Wm. Buckland, Dean of Westminster. From an early period Mr. Bompas took an interest in astronomy; his special studies were on periodic meteor showers, and he latterly devoted his attention to the Zodiacal Light and the solar motion in space. He was elected a Fellow of the Society on the 14th of December 1894; he was also a Fellow of the Royal Geographical Society, the Geological Society, the Palæontological Society, and other institutions. He died on the 23rd of May 1905, after a long illness, leaving a widow and four children.

Everard Home Roberts Coleman was born in London in January 1818. Like his father before him, he was educated at Christ's Hospital. He was one of the forty boys in the Mathematical School, a branch of the Hospital founded by Charles II. with the view of training lads for the Navy. An interesting occurrence of his school days was a visit of the King (William IV.), the Queen, and Princess Victoria, when his Majesty's attention was attracted by a drawing by young Coleman of the island of St. Helena. The King took it from the boy's hands, and, after explaining it to the royal party, asked to be allowed to keep it. Soon afterwards Coleman received from the King an appointment in the Admiralty, and five years later was transferred to the Record and Registry Office for Shipping and Seamen, where he became

Assistant Registrar, an office which he held till his retirement seventeen years ago. He was well known as an archæologist and antiquarian, was the oldest living member of the London and Middlesex Archæological Society, and one of the original contributors to *Notes and Queries*; he was also a Fellow of the Royal Geographical and Historical Societies. Though of a retiring disposition, he took an interest in public affairs in connection with the district of St. Pancras, in which he lived, and in local charitable institutions.

He died on the 28th of January 1906, at the age of 88, and leaves a widow, a daughter, and seven sons. With one exception Mr. Coleman was the oldest Fellow of the Royal Astronomical Society, having been elected in June 1853.

Ralph Copeland was born on the 3rd of September 1837, at Moorside Farm, near Woodplumpton, in Lancashire, and while still a child lost his father. He received his first instruction from a handloom weaver, who taught his pupils while working at his loom, until he at the age of about eight years proceeded to the grammar school of Kirkham. In 1853 he went to Australia and spent five years in the colony of Victoria, most of the time on a sheep run at the foot of the Australian Alps, though he was also for some time infected by the then raging mania for gold digging and made his way to the wild Omeo district. In after years Copeland was always fond of recalling incidents from this stirring period of his life, and it is much to be regretted that he could never be persuaded to write down his reminiscences, as they would have formed most entertaining reading.

Rough as the life was which he led during these five years, Copeland did not neglect to cultivate his mind, and it was during that time that he became deeply interested in astronomy. At his request his mother sent him a small telescope, and by means of this and a few popular books he made his first acquaintance with the heavens. Finally his thirst for knowledge decided him to leave Australia, and he started for home in the summer of 1858 in a clipper *viâ* Cape Horn. On the voyage he made experiments as to the visibility of stars in daylight in the tropics, and succeeded in keeping *Jupiter*, and even *Sirius*, in sight until the Sun showed above the horizon; but after glancing at the Sun he was unable to find *Sirius* again, though he succeeded in picking up *Jupiter* for a short time.* He also followed with close attention the appearance and rapid development of Donati's Comet. He had wished to enter Cambridge University, but had to give up this plan and eventually entered the works of Beyer, Peacock & Co., locomotive engineers, of Manchester, as a volunteer-apprentice. Here he carried on the study of the stars commenced in Australia, and was fortunate enough to find

* See *Copernicus*, vol. iii. p. 204.

among his fellow-apprentices several who shared his tastes and joined him in fitting up a small observatory for a 5-inch refractor by Cooke, at West Gorton, near Manchester. Copeland's first recorded observation was of the occultation of κ *Cancri* on the 26th of April 1863, which Mr. Dawes communicated to the *Monthly Notices* (vol. xxiii. p. 221), and which attracted some attention at the time, as the disappearance of the star at the dark limb did not appear to be instantaneous, a fact which was denied by some observers but confirmed by others.

In the end Copeland resolved to desert mechanical engineering and to devote his life to astronomy, being also influenced by the bad prospects of trade in Lancashire due to the cotton famine during the American Civil War. Although he had been a married man for about five years (he had married a first cousin, Susannah Milner, in 1859) and was the father of a little girl, he made up his mind to study at a German University. In the spring of 1865 he matriculated in the University of Göttingen and commenced the study of astronomy, physics, and mathematics. Among his fellow-students were Behrmann, Börgen, and Schur, with whom he not only attended the lectures of Klinkerfues, Weber, Stern, and other professors, but also had the opportunity of becoming familiar with the use of astronomical instruments. The observatory was in charge of Klinkerfues, whose excellence as a teacher and charm of manner greatly endeared him to his pupils. In July 1866 Copeland had the misfortune to lose his wife, who died leaving him an infant son. In the summer of 1867 Börgen and he decided to carry out a considerable piece of work with one of the meridian instruments in the observatory, and as the Astronomische Gesellschaft was about to organise zone observations of all stars down to the ninth magnitude north of $-2°$ declination, they chose the zones $-1°$ and $-0°$ and commenced observing them with the Reichenbach transit circle on the 2nd of June 1867. Early in the following year Copeland took up his residence at the observatory, where his fellow-observer had also rooms, and in January 1869 the last zone was observed, while the reductions were so far advanced that the resulting catalogue of star-places could be published in the following summer. The work had been commenced before the programme of the zone work of the Gesellschaft had been settled, and it turned out that the plan adopted by the two Göttingen observers differed from that of the international undertaking, as the places of standard stars had been taken from the *Nautical Almanac*, while the stars below the ninth magnitude observed by Lalande and Bessel had not been re-observed. The catalogue was therefore not accepted by the Council of the Gesellschaft as a part of their undertaking, and the zone $-2°$ to $0°$ was some years later assigned to the Nicolajew Observatory; but as the Nicolajew Catalogue ($-2°$ to $+1°$) did not appear till the year 1900, the Göttingen Catalogue was for thirty years the chief modern authority for the

zone in question, while its earlier epoch and its accuracy make it permanently valuable in cases of proper motion.

Before the actual publication of the star catalogue Copeland had already entered on a different line of scientific work. Early in 1869 it was decided to send out a German Arctic expedition under Captain Koldewey, the aim of which should be to explore the east coast of Greenland as far north as possible. It occurred to Koldewey that it would be of great interest to measure an arc of meridian so near the Pole. Börgen, whom he consulted as to the feasibility of the idea, pointed out that it would be impossible to attempt to reach results of permanent value, since the expedition could not be devoted to this work alone, but that it would be most useful to make a detailed geodetic reconnaissance, on which at some future time a regular measurement of an arc could be based. Should this be made part of the work of the expedition he would be disposed to join it, but in that case Copeland ought also to join, since one astronomer could not possibly carry out the work alone. On hearing this the same evening, Copeland at once was fired with enthusiasm at the prospect of taking part in a scientific investigation of a novel kind, and spent half the night talking about the methods to be followed and the instruments to be used.* The preparations for the expedition were rapidly pushed on, while the two friends at the same time put the finishing touch to their studies by taking out the degree of Doctor of Philosophy, Copeland's dissertation being on the orbital motion of *α Centauri* (*Über die Bahnbewegung von α Centauri*, Göttingen, 1869, 24 pp. 8°).

The expedition started from Bremerhafen on the 15th of June 1869. It consisted of the *Germania* (on board which Copeland was) and a small sailing vessel, the *Hansa*. The latter was to have returned the same autumn after unloading stores, but it became unfortunately separated from its companion off the east coast of Greenland and was crushed in the ice, though the crew, after drifting on an ice floe for seven months, succeeded in reaching one of the Danish settlements on the west coast. The *Germania* safely reached the east coast, and wintered in latitude 74° 32′. Copeland showed himself as a most useful member of the expedition owing to his training as a mechanical engineer, as well as by his skill in the use of the rifle, whereby he contributed greatly to keeping the larder supplied with fresh meat. During the winter he and Dr. Börgen made regular meteorological and magnetic observations, and in February 1870 the work was commenced of selecting the nearest stations and erecting cairns on them for the geodetic work. In the course of the next two months stations slightly more distant were visited by Copeland without the help of his friend, who had been badly wounded by a bear in the beginning of March, whereby much precious time

* The writer is indebted to Professor Börgen for these particulars, which he wishes to be put on record here, as it was stated in an obituary notice after Copeland's death that he joined the expedition from love of adventure.

was lost. It was, therefore, not till the beginning of May that a base, 709 metres in length, was measured close to the ship, after which the two observers started northward in a sledge. But the season was by that time too far advanced, the snow was too soft, and a rapid thaw set in early in June, rendering sledge travelling impossible. Instead of continuing operations as far as 75° 45′, as intended, it became necessary to stop at 75° 11′·5. The observations were made with an altazimuth with 5-inch circles, the latitude of the two end stations being determined by altitudes of the Sun. A good deal of valuable experience had been gained as to the best hours for taking observations and the most suitable localities for stations, which ought to be of great use for future geodetic observers in high latitudes. The results were published in the second volume of the work *Die Zweite Deutsche Nordpolarfahrt* (Leipzig, 1874).*

Soon after his return from Greenland Copeland was appointed Assistant Astronomer at Lord Rosse's Observatory at Birr Castle, and entered on his duties there in January 1871. In the following December he married Theodora, daughter of the distinguished orientalist Professor Benfey, of Göttingen. This marriage brought him three daughters and a son. At Birr Castle Copeland was for the first two years chiefly occupied with the observations on the Moon's radiant heat embodied in Lord Rosse's paper on this subject in the *Philosophical Transactions*, 1873. In 1874 he was appointed Assistant in the Dublin University Observatory at Dunsink, but was granted leave of absence to accompany Lord Lindsay to Mauritius to observe the transit of *Venus*. On the outward voyage, in the yacht *Venus*, a call was made at the small uninhabited island of Trinidad, in the South Atlantic, where Copeland was fortunate enough to discover a great tree-fern (*Cyathea Copelandi*), groves of which are found only in the loftier and nearly inaccessible parts of the island. The observations of the transit were only partly successful, owing to cloudy weather. On the eventful day Copeland observed with a 6-inch equatorial and double-image micrometer.

This expedition was the beginning of his connection with the observatory of Lord Lindsay (now Lord Crawford) which lasted for the remainder of his life. He stayed only a little over a year at Dunsink (where he observed red stars with the transit circle), and took charge of the Dun Echt observatory in the summer of 1876 in succession to Mr. Gill. He was singularly well suited to the post, as his great mechanical skill was particularly useful in an observatory where an unusually great number of astronomical and physical instruments had been collected, while his thorough knowledge of scientific literature and fondness of rare books made him a valuable help to Lord Crawford in forming a great astronomical library. The Mauritius expedition had left a troublesome legacy in the shape of an immense amount of

* A short account of the geodetic work (with a map) is given by Dr. Börgen in the *Vierteljahrsschrift d. a. G.*, vol. vi. p. 280.

unreduced observations connected with the latitude and longitude work, which gave Copeland a great deal to do during the first five or six years at Dun Echt. The results were brought out in 1885 in a quarto volume of more than 500 pages, the third volume of the *Dun Echt Observatory Publications*. An interesting result of this work was the discovery of a considerable deflection of the plumb line in the island of Mauritius, the sum of the observed deviations at the Government Observatory and the German station being no less than $56''{\cdot}6$, a natural consequence of the island being but the exposed summit of a mountain some 15,000 feet high, standing on the floor of the ocean, while the observations were made some 3,000 feet below the highest points.

Among the instruments at Dun Echt Copeland specially devoted himself to the 15-inch refractor, with which he regularly observed every comet which became visible, while he for some years also computed elements and ephemerides of them. Most of these computations were published in the *Dun Echt Circulars*, by means of which Lord Crawford for ten years distributed news of discoveries of comets, &c. In January 1881 Copeland became joint editor of "*Copernicus*, an international Journal of Astronomy" (3 vols. 1881–84), which, though printed in Dublin, was the organ of the Dun Echt Observatory. As Copeland was always somewhat inclined to postpone the final completion and publication of his scientific work, it was fortunate that this journal for some years supplied a much-needed stimulus, and some of his best work is accordingly to be found in *Copernicus*. The end of the year in which he settled at Dun Echt witnessed the outburst of Schmidt's Nova *Cygni*, the remarkable spectrum of which was regularly observed by Copeland in January and February 1877, and on the 2nd of September he made the then totally unexpected discovery that the spectrum had become reduced to a single bright line—a discovery which forms an epoch in the history of our knowledge of temporary stars. The spectroscope was also turned on every comet visible at Dun Echt, and a specially rich harvest of results was furnished by the two great comets of 1881, Wells' Comet 1882 I, and the Great Comet of 1882. In the spectrum of Wells' comet Copeland and his assistant, Mr. Lohse, noticed on the 27th of May the presence of the yellow sodium line, both components of which were beautifully seen some days later, while the widely opened slit allowed the image of the comet to be clearly seen in the light of the D lines. Even these interesting observations were surpassed by those made on the 18th of September 1882, in full daylight, of the great comet close to the Sun. Not only were the bright D lines seen again, but also a whole row of bright lines, the best defined of which were afterwards identified with prominent iron lines, while the numerous dark Fraunhofer lines of the daylight spectrum supplied a background which showed that the comet lines were displaced towards the red end of the

spectrum, indicating that the comet was receding from the earth. All these important observations are published in vol. ii. of *Copernicus*.

In October 1882 Copeland started for Jamaica, where he successfully observed the transit of *Venus*. During his stay in the island it occurred to him that it would be of interest to test the suitability of the slopes of the Andes for astronomical observation, and, as Lord Crawford liberally met the necessary outlay for this digression, Copeland made his way across the Isthmus of Panama towards the end of December. As the expedition had not been thought of before leaving home, his outfit was rather scanty, consisting of some meteorological instruments, a small Vogel spectroscope, and a six-inch refractor by Simms, the fine equatoreal mounting of which had to be left behind as far too heavy for mule transport. In its place a light mounting was despatched from Dun Echt, together with a Browning automatic spectroscope, but they were delayed on the way, owing to the war between Chile and Peru, and did not reach him till the 2nd of June 1883, and then only in a damaged condition. He had first intended to go to Quito, but on reaching Gauyaquil this was found to be impossible, owing to revolution, so he had to go on to Peru. Landing at Mollendo on the 2nd of February, he proceeded to Arequipa by the interesting railway and utilised an enforced delay of a week in that town to get a 6-inch lathe transformed into a very fair equatorial mounting. The rainy season was now in full swing, and when he reached Vincocaya (14,360 feet above the sea) nothing could be done there, for which reason he went on to La Paz, in Bolivia, across the Lake of Titicaca, to gain experience of the means of transport and the state of the sky in that country. He established himself at Puno, on Lake Titicaca (12,500 feet), from the 17th of March to the 2nd of June, after which he again observed at Vincocaya till the 27th of June before embarking for Panama. With the Vogel spectroscope he found a number of stars with bright line spectra and several star-like planetary nebulæ, and would doubtless have accomplished much more in this direction if his instrumental equipment had been better. Though the direct results of his observations were not numerous the expedition had shown the great possibilities of a thoroughly equipped astronomical expedition or a permanent observatory in the regions visited by him; and in after years, when Harvard College Observatory had established a branch at Arequipa, it was a great satisfaction to Copeland to feel that he had been the pioneer of Peruvian astronomy, although he had rather advocated the choice of some place between La Paz and Lake Titicaca. His "Account of some Recent Astronomical Experiments at High Elevations in the Andes" appeared in vol. iii. of *Copernicus*, which volume also contains a short account of his visit to various American observatories in August 1883 on his way home.*

* Two lengthy "Reisebriefe aus Südamerika," dated February 1883, are

After his return home in September 1883 Copeland found enough to do in preparing his results for publication and seeing the Mauritius volume through the press. He next resumed his spectroscopic work whenever a special opportunity offered itself, as on the appearance of the new star in the nebula of *Andromeda* and on the discovery of Mr. Gore's variable star in *Orion* (*Monthly Notices*, vols. xlvi. and xlvii.). In 1886 the observatory was enriched by a magnificent star-spectroscope made by Messrs. Cooke & Sons. Almost the first time this instrument was directed to the nebula in *Orion* it revealed the presence of the D_3 line in its spectrum, and soon afterwards of a very faint line at W. L. 447·6 (*Monthly Notices*, vol. xlviii. p. 360). Encouraged by this unexpected discovery Copeland commenced a regular spectroscopic survey of the brighter nebulæ, and (judging from private letters written at that time) these observations made with a very powerful instrument would, if persevered in, have produced very valuable results, but his removal from Dun Echt unfortunately caused them to be interrupted, and they were never resumed. In 1887 an observing station was established on the top of the Barmekin Hill, close to Dun Echt, for the purpose of studying the low Sun spectrum by the aid of a Rowland grating and an ingenious and rapid recording apparatus; but his journey to Russia in the summer of that year to observe the total eclipse of the Sun (of which he saw nothing, owing to clouds) prevented Copeland from sharing in this interesting work, which Dr. Becker carried out most successfully. During that year and the following one every spare moment was devoted to the revision and passing through the press of the *Catalogue of the Crawford Library*. It had always given Copeland great pleasure to acquire rare and valuable books and memoirs for this great collection, particularly in the department of comets, and almost to the last year of his life he lost no reasonable opportunity of adding to it. The catalogue, which was published in 1890, is one of the most valuable guides to astronomical literature (particularly previous to 1700) and is simply indispensable to the collector.

The years which Copeland was destined to spend at Dun Echt had now come to an end. They were undoubtedly the happiest years of his life. Surrounded by his family and free from all distraction by extraneous duties or routine work, he was able to make full use of the splendid opportunities for original work afforded by the instruments and library under his charge. No wonder that he was very attached to the place and was glad to return to it several times to spend his summer holidays in his old house and to meet again many friends he had made in the neighbourhood.

In August 1888 Professor Piazzi Smyth resigned the offices of Astronomer Royal for Scotland and Professor of Astronomy in

published in the *Deutsche Geographische Blätter* (vol. vi. Bremen, 1883); they give a most vivid description of his journey from Mollendo to La Paz and of a trip to the Island of Coati in Lake Titicaca.

the University of Edinburgh. For some years previously the question of reorganising the Edinburgh Observatory had been under consideration, and it had even been proposed to hand it over to the University. But this was prevented by the noble liberality of Lord Crawford, who offered the Government to present the whole of the instrumental equipment of his own observatory, together with his astronomical library, to the nation, on the sole condition that the thus enriched Edinburgh Observatory should be maintained as a Royal Observatory. The offer was accepted and Copeland was appointed to the vacant offices on the 29th of January 1889, and removed to Edinburgh in the following April. The first subject to engage his attention was naturally the selection of a site for the new observatory, and after a careful examination of the neighbourhood of Edinburgh he finally chose Blackford Hill, as being south of and quite clear of the smoke of the city, and yet not at too great a distance from the University where he had to lecture. From the beginning he was deeply interested in his professorial duties, and though it was at first uphill work to attract students to the astronomical lectures (which his predecessor had managed to evade for many years) he gradually succeeded in forming an astronomical class, the members of which gave evidence at the annual examination of having benefited well by the lectures as well as by the practical demonstrations in the observatory.

In 1891 Copeland read a paper before the British Association, at its Cardiff meeting, "On the Probable Nature of the Bright Streaks on the Moon" (*Report*, 1891, p. 576). He pointed out that the streaks are only visible when the light falls more or less closely in the line of sight, while they come into view quite regardless of the inclination of the surfaces on which they occur. He concluded that each elementary portion of the streak surface is of a form which is symmetrical to the spectator from whatever point it is seen, a condition which the sphere alone seems to fulfil; and he therefore suggested that the streaks are produced by a material pitted with minute cavities of spherical figure, or strewn over with minute, more or less transparent, solid spheres. To test this hypothesis a plaster model of the Moon was made, on which the bright streaks were represented by lines of minute spherules of transparent glass attached to the surface, which were found to possess the desired property of remaining inconspicuous under cross light, while they flashed out brilliantly when lit up from the front. When suitably illuminated the phases of the model were seen, on photometric examination, to follow a law not very unlike that of the lunar phases found by Zöllner. The short note on this subject does not seem to have attracted much attention; it was to have been followed by a more detailed memoir, which, through press of other work, was never written.

While the new Observatory was being planned and erected Copeland had, of course, only the resources of the old Observatory

on the Calton Hill at his disposal; and he was therefore, to his regret, only able to a limited extent to observe the new star of 1892 in *Auriga* on its first appearance (*Trans. R. S. Edinb.* vol. xxxvii. p. 51), though he had the pleasure, on its reappearance in the autumn, of studying its spectrum at Dun Echt, where the 15-inch refractor had not yet been dismounted. But he took the opportunity offered by this transition period to make arrangements for a new reduction of Henderson's meridian observations, in connexion with which he paid a visit to Berlin in 1893 to consult Professor Auwers on various points. The work turned out to be much more considerable than anticipated; from 1896 it has been carried on by Dr. Halm, and at Copeland's death the printing of the resulting star catalogue for 1840 had not yet been completed. His holidays, whether spent at Dun Echt or elsewhere, often merely meant a change of work, as when he, in the summer of 1894, travelled about the west of Scotland and the north and east of Ireland in order to interview people who had seen a brilliant meteor which, on the 18th of May, at 8 P.M. (in broad daylight), had passed from N.W. to S.E. He succeeded in computing a path agreeing well with the necessarily very rough observations, but his usual wish to postpone the publication of a paper till after repeated applications of the file prevented in this, as in other instances, the publication of his results.

In the meantime the new and stately Royal Observatory on Blackford Hill was approaching completion, the instruments at Dun Echt were dismounted, packed, and forwarded to their new destination, and in May 1895 Copeland took possession of his new home. The unpacking and mounting of the instruments occupied most of that year, so that it was not till April 1896 that the Observatory could be formally opened by the Secretary for Scotland, Lord Balfour of Burleigh, in the presence of Lord Crawford, who gave an interesting account of the origin of the new institution. It might now have been expected that Copeland would have resumed the vigorous activity which he had displayed at Dun Echt, but at that very time it began to be evident that his energy and capacity for work had sensibly declined, and there can be no doubt that the heart disease to which he eventually succumbed had already then commenced to undermine his strength. He never again engaged in any lengthy investigation; still his enthusiasm and love of science induced him to undertake three expeditions to observe total eclipses of the Sun. In 1896 he went to Vadsö, in Finmark, and was (as in 1887) much disappointed at seeing nothing of the eclipse, for which he had made elaborate preparations, bringing with him a 40-foot telescope, with 4-inch Dallmeyer lens, mounted on trestles so as to point exactly to the Sun at mid-totality. He had, however, what to him, as an old Arctic traveller, was the great pleasure of being among the first to greet Nansen on his arrival at Vardö, in the *Windward*.

Undaunted at this second failure, he accepted the invitation of the Joint Permanent Eclipse Committee to take part in the observations of the eclipse of the 22nd of January 1898 in India. He took his 40-foot telescope with him, this time arranged as a horizontal telescope, in which the image was received on 18-inch plates moved by clockwork, while a direct-vision prism, mounted on a slide in front of the object-glass, could be drawn into position by an attendant, transforming the telescope into a prismatic camera. To increase the chances of success he on this occasion selected a station at some distance from other observers, and established himself at Ghoglee, in the Central Provinces, where he was favoured by a cloudless sky. He was equally successful two years later, when he went to Santa Pola, on the south-east coast of Spain, and observed the eclipse of the 28th of May 1900. Of both these expeditions preliminary reports only appeared in the *Proceedings of the Royal Society*, reprinted in the Appendices to the *Monthly Notices*, vols. lviii. and lx.

The first astronomical event of the new century, the appearance of Nova *Persei*, was duly announced in No. 54 of the *Edinburgh Circulars*, which Copeland issued in continuation of the *Dun Echt Circulars*, and that number turned out to be the last one he was to send out, while the spectroscopic examination of the star which he made during the earlier stages of its development was the last astronomical work he was to take part in. In the summer of 1901 he had a severe attack of influenza, from which it may be said that he never recovered. To try to shake off the effects of the illness he went to Wiesbaden in May 1902, but after hurrying to catch a train on the German frontier he was seized with an attack of angina pectoris, which unhappily was but the first of very many similar attacks during the next three years. He had reluctantly to give up his lectures, but he could not give up the hope of still being able to occupy himself with scientific subjects, and, as he was unable to mount the stairs to his beloved "optical room," he made, early in 1904, arrangements for darkening one of the rooms on the ground floor of the Observatory, in order to resume some of the optical experiments of which he had always been so fond. But he was never able to attempt this work. In the spring of 1904 he proposed to retire, but, as the pension offered him was exceedingly small, he was compelled to give up the idea; indeed, for some months in the summer and autumn of that year he was so ill that his death did not seem far distant. Once more his health seemed to improve; after a visit to the seaside in the beginning of 1905 the dreaded attacks ceased in the month of April, and he was tolerably well, though rather weak during the summer. But in the autumn the ordinary symptoms of heart failure appeared, together with other complications, and he passed away peacefully on the morning of the 27th of October, after having been confined to his bed for a little over a fortnight.

Copeland was a man of highly cultured mind, who made

good use of the many opportunities of acquiring knowledge which he enjoyed throughout his life. Even during the last few years he tried to forget his sufferings by taking up the study of Persian, and was delighted to be able to read Omar Khayyam in the original language. His character was open, sincere, and generous, he was always anxious to befriend and help anybody whenever he could, and he never shirked any trouble or work to answer inquiries even from people who had no claim on his time. He will be remembered with warm affection by all who had more than a passing acquaintance with him.

He was elected a Fellow of this Society on the 9th of January 1874.

[The Council are indebted to Dr. J. L. E. Dreyer for the above obituary.]

John Dansken was born at Glasgow in 1836, and educated at the Athenæum and Glasgow University. His profession, in which he became well known, was that of a surveyor; in later life he took a considerable share in public affairs, and was placed on the Commission of the Peace for Lanarkshire. He was an enthusiastic amateur astronomer, and built for himself an excellent private observatory containing a 13-inch reflector, several refractors, and a transit instrument. He also formed a valuable collection of astronomical books.

He was elected a Fellow of the Society in 1892, and died suddenly on the 1st of November 1905.

Adam Storey Farrar was born in London in 1826, and educated at Oxford, taking his degree in 1850. At Oxford he won the Arnold prize for history in 1851 and Denyer's theological prize, and was elected to a Fellowship at Queen's College, which he held from 1852 to 1863, holding also a Tutorship at Wadham College for some years. In 1862 he was Bampton Lecturer. In 1863 he married, and shortly afterwards accepted the Professorship of Divinity and Ecclesiastical History in the University of Durham, which he held for forty years. He became a Canon Residentiary of Durham in 1878, and in 1902 was elected to an honorary Fellowship at his old Oxford college.

Astronomy formed but one of many interests which he kept up with undiminishing zeal until his death. It is doubtful if he ever used a telescope, but he was very keen for any observation that could be made with the naked eye. He was moreover an enterprising and critical reader of astronomical works, new and old, and delighted to beguile his leisure by posing his friends with many a crooked question.

He was elected a Fellow of the Society in 1858, and died on the 11th of June 1905.

Edmund Beckett, first Baron Grimthorpe and fifth Baronet, was born at Carlton Hall, near Newark, on the 12th of May 1816. He was the eldest son of Mr. Edmund Beckett, M.P. for

the West Riding of Yorkshire, who in 1816 had assumed the name of Denison, but reverted to that of Beckett on succeeding to the Baronetcy in 1872. In like manner the subject of this notice, who had the assumed name of Denison, returned to that of Beckett on succeeding to the Baronetcy in 1874. In 1886 he was raised to the Peerage as Baron Grimthorpe with special remainder, in default of male issue, to the heirs male of his father.

Mr. Beckett Denison was educated at Doncaster, Eton, and Trinity College, Cambridge, where he graduated as 30th Wrangler in the Tripos of 1838. He did not, however, make his mark at the University.

He was called to the Bar at Lincoln's Inn in 1841 and joined the Parliamentary Bar, where he practised until 1881. In 1854 he was made Q.C., and in 1877 was appointed Chancellor and Vicar-General of York Diocese and Province.

In his legal career he had a practice rarely equalled, and his income at the Parliamentary Bar for many years was very large. Few men knew more of ecclesiastical law. He was endued with courage and great self-confidence, with a tenacious memory which enabled him to recall the evidence given by a witness years before ; and he was merciless in exposing inconsistency.

In 1866 Mr. Beckett Denison published the well-known work *Astronomy without Mathematics*, a singularly lucid and vigorous elementary treatise on the principles of the science, which has passed through many editions.

Of greater importance was his delightful treatise on *Clocks, Watches, and Bells*, which has become a recognised text-book in the watchmaking trade. In this book he is "a clear exponent of other men's work; he suggests improvements and points to future discoveries, and the work breathes the spirit of a man who had touched with his own hands all that he describes." When President of the Horological Society none of its members knew more than he did of the construction of clocks and watches. He was responsible for the design of the Big Ben clock at Westminster, and the credit for that remarkable clock undoubtedly belongs to him.

Lord Grimthorpe strayed into many paths, and all he did was stamped with originality. He was an authority on architectural questions and wrote a book on *Building, Civil and Ecclesiastical*, and there was not a better locksmith in England.

He was a prolific writer and controversialist. His style, though infelicitous and occasionally somewhat involved, was vigorous, caustic, and racy.

He directed the renovation of St. Albans Cathedral, and expended out of his own pocket over 100,000*l.* in its restoration. Besides this he gave munificent assistance towards the restoration of many churches, parsonages, and schools in the country.

In 1845 he married a daughter of the late Bishop Lonsdale, who died in 1901, leaving no issue.

Lord Grimthorpe was elected a Fellow of the Royal Astro-

nomical Society on the 9th of November 1866, and he served on the Council in 1870–3, 1875, and 1878–80.

He latterly lived in retirement at his residence, Batch Wood, St. Albans, where he died on the 29th of April 1905, in his 89th year.

The Rev. SAMUEL JENKINS JOHNSON was the only son of the Rev. S. Johnson, and was born on the 14th of March 1845 at Atherton, in Lancashire, being descended from an old Lancashire family. He early showed a great love for astronomy, and when no more than nine years old began to collect such mentions of celestial phenomena as he could find in the Greek and Latin classics. His great delight at school was to gather his playfellows in a corner of the playground and give them a lecture on astronomy. He decided to take orders, and with this view he matriculated at St. John's College, Oxford, where he remained for three years, when he took his degree. He was ordained deacon in 1868, and priest in 1869; in 1868 he was licensed to the curacy of West Houghton, Lancashire, and to that of Lytham in 1870. At the end of the latter year he became vicar of Upton Helions, Devon, the church of which he entirely restored. In 1879 he married Miss Mary Drew, and migrated to Abbenhall, Gloucester, where he spent a year in restoring the church; and finally, in 1882, settled at Melplash, Bridport, where the remainder of his life was spent.

Mr. Johnson was elected a Fellow of this Society on the 8th of March 1872, and between that time and the year of his death contributed no fewer than thirty-seven papers to the *Monthly Notices*. These are mostly short notes on ancient and future eclipses, or on his observations of eclipses, transits, occultations, &c. In *Monthly Notices*, vol. liv. p. 142, he published a note on the influence of the full Moon on the weather. His records, kept for fifteen years, appeared to show that there is no ground for the view held by Sir John Herschel, Humboldt, &c., that the full Moon has some effect in dissipating clouds. In 1887 he presented to the Society a large manuscript volume containing particulars of all eclipses visible in England from A.D. 538 to 2500. In 1869 he published a small work, *Eclipses and Transits in Future Years*; he was also the author of *Eclipses Past and Future* (1874) and *Historical and Future Eclipses* (1896). In 1882 he went to Marseilles to observe the transit of *Mercury* of the 6th of December; and in 1900 made a journey to Navalmoral, in Spain, where he successfully observed the total solar eclipse of the 28th of May. He published his observations, with a sketch of the corona, in *Monthly Notices*, vol. lx. p. 590.

Mr. Johnson suffered from gout, and had been for some time failing in health; this became more marked after the death of his wife in 1904. Though scarcely fit for the journey he went to Burgos, where he was successful in observing the total solar eclipse

of the 30th of August 1905. He returned about the 10th of September, and at once resumed his parochial duties. On the 4th of October he attended the Church Congress at Weymouth, but his strength was failing, and he died somewhat suddenly on the 9th of October.

His great interest in astronomy never led him to neglect his work as a clergyman. He made great improvements in his church and parish generally, and was well known among the poor for his kindly interest and warm-hearted generosity. He was attentive to his duties to the last, and only three days before his death had walked three miles over a bad road to the end of his parish. He leaves a son and a daughter, to the former of whom (Mr. S. T. Johnson) the Council are indebted for most of the particulars given in this notice.

Mr. Johnson left a small sum in trust, the income to be devoted to the continuation in various almanacs of his predictions and diagrams of eclipses and occultations.

Charles Jasper Joly was the son of the Rev. J. Swift Joly, of Athlone, and was born in 1864. As a boy at Galway Grammar School he was reputed clever generally, but was not considered to have any special aptitude for the mathematical sciences; indeed it was only as he approached maturity that his remarkable powers became apparent. In 1882 he entered Trinity College, Dublin, taking a scholarship and ultimately the mathematical studentship of his year. From Dublin he went to Berlin, and was for some time a student of experimental physics in the laboratory of Helmholtz and Koenig. In 1887, however, on the death of his father, he returned to Ireland, and read for a Trinity Fellowship, which was attained in 1894. During the years of preparation he acquired a magnificent grasp of Quaternions and of every branch of Mathematical Physics, and almost immediately after his election a succession of memoirs, broken only by his death, showed his masterly power as an investigator.

In 1897 he succeeded Dr. Rambaut as Andrews Professor of Astronomy in the University of Dublin and Royal Astronomer of Ireland; he was elected a Fellow of the Royal Astronomical Society in 1898, and took part in the successful Spanish eclipse expedition of 1900, which was sent out by the Royal Dublin Society and the Royal Irish Academy. But his time during the four years succeeding his appointment was chiefly occupied in the gigantic task of preparing a new edition of the work on Quaternions of his great predecessor, Hamilton. A large amount of additional matter was contributed by Joly himself, and the publication of the first volume in 1899 and the second volume in 1901 created a notable revival of interest in quaternion analysis; this was further stimulated by his own subsequent investigations, especially a memoir on *Quaternions and Projective Geometry*, which occupies over 100 pages in the *Phil. Trans.* of 1903.

In 1902 Joly became Secretary of the Royal Irish Academy, and brought out a new edition of Preston's *Theory of Light*. In 1904 he was elected a Fellow of the Royal Society, and in 1905 a *Manual of Quaternions* appeared from his pen, in which the Hamiltonian manner of establishing the laws of Quaternions is replaced by one leading much more easily and directly to the desired goal.

Joly took a considerable part in scientific life in Ireland ; he was a member of the Council of the Royal Dublin Society, and a Trustee of the National Library of Ireland ; at the time of his death he was President of the International Society for the Study of Quaternions. For Trinity College he performed many services, especially in connection with projected reforms.

His knowledge of literature, especially of Dante and Italian literature, was profound ; and he excelled in the physical life also, being an excellent mountaineer and a member of the Alpine Club.

His death from fever on the 4th of January, 1906, at the early age of forty-one, is a great loss to science.

He is survived by Mrs. Joly, a daughter of the late R. W. Meade, Esq., and by three children.

Thomas Edward Knightley was born in 1824. He adopted the profession of architect and practised in London ; amongst his principal works are the new buildings for the Birkbeck Bank and the Queen's Concert Hall, Langham Place. He was district surveyor for Hammersmith for forty years ; he held other public appointments, and was on the Court of the Cordwainers' Company. He was elected a Fellow of the Society on the 13th of March 1896, but never took any active part in astronomical work. He died on the 4th of September 1905.

William Robert Maurice Waugh, a Congregational minister who throughout his long life was deeply interested in astronomy, was born the 25th of July 1818 in London. His observational work related chiefly to the planets, especially *Jupiter* ; but he took much interest in other astronomical work, particularly observations of star colours, and he was for a long period the director of the Coloured Star Section of the Liverpool Astronomical Society, a society which he joined in 1887. His knowledge of all branches of astronomy, and of most branches of physics, was very extensive, and he was an excellent lecturer on scientific subjects. He was for several years Director of the *Jupiter* Section of the British Astronomical Association, and his own observations formed an important part of the work recorded in the Memoirs of that section. He was an excellent draughtsman, and his drawings of *Jupiter* were marked by great accuracy of detail and delicacy of finish. He contributed the additional matter on *Jupiter* to the fourth edition of Webb's *Celestial Objects*. His observatory at Portland, Dorset, contained a

12½-inch reflector and a 4½-inch refractor, mounted equatorially.

Mr. Waugh was elected a Fellow of the Society in 1888, and died the 25th of November 1905.

Sir William James Lloyd Wharton was born in London in 1843, the son of Mr. R. Wharton, County Court Judge of York, and entered the Navy at the age of 14. In 1865 he became lieutenant, and in 1872 commander, being appointed to surveying service in the Mediterranean and the East African coast; an investigation of currents in the Bosphorus which followed brought him to notice as a scientific officer, and his authorship of the standard work on *Hydrographical Surveying* led to his appointment in 1884 to the office of Hydrographer to the Admiralty, which he held until failing health compelled his retirement in 1904. He was elected a Fellow of the Royal Astronomical Society in 1877, and of the Royal Society in 1886, and served for many years as one of the representatives of the Royal Society on the Joint Permanent Eclipse Committee. In 1895 he was promoted to the rank of rear-admiral (retired), and in 1897 received the honour of a K.C.B.

Sir William Wharton's interest in astronomy was manifested by the persistent exercise of his influence with the Board of Admiralty towards obtaining from time to time accession to the means and appliances of the Royal Observatories at Greenwich and the Cape of Good Hope.

He observed successfully the transit of *Venus* in 1874 at Rodriguez, and again in 1882 in the Straits of Magellan; whilst the skill with which he observed with sextant and artificial horizon renders the numerous astronomical positions determined by him in many parts of the world unchallengeable for their accuracy.

He died at the Cape Observatory while staying there as the guest of Sir David Gill during the visit of the British Association to S. Africa. Lady Wharton and several children survive him.

Otto Wilhelm von Struve was born on the 7th of May 1819 at Dorpat. When he was a child seven years of age the Gold Medal of the Royal Astronomical Society was awarded to his father, Wilhelm Struve, who was Director of the Dorpat Observatory—an honour destined in after years to be conferred on himself, and, in the still more distant future, on his son.

His official connection with astronomy began in 1837, when he commenced to serve as assistant to his father in double-star work at the observatory; at the time he was still a student at the university. Meanwhile the Russian Government, guided by the elder Struve, had established the national Russian Observatory at Pulkowa; and, soon after taking his degree, Otto Struve was appointed, with C. A. F. Peters, to the office of Assistant Astronomer there. His energies were now devoted chiefly to

fundamental determinations; using 400 stars, of which the majority were double stars observed by his father at Dorpat, he undertook an exhaustive investigation on the constant of precession and the proper motion of the solar system. The results were communicated to the Academy of St. Petersburg in November 1841, and printed in their Transactions. This memoir furnished the occasion of the Royal Astronomical Society's award of their Gold Medal in 1850, the author having been elected an Associate two years previously.

In 1852 he became a member of the St. Petersburg Academy of Sciences, and in 1862 succeeded his father as Director of the Pulkowa Observatory, with which institution his whole scientific life is identified. His work centred now, as before, chiefly on double stars and fundamental astronomy; but he took the greatest interest in geodetical investigations, and as consulting astronomer to the general staff and to the hydrographical department he was the chief adviser of the Russian Government in matters related to astronomy and geodesy. Co-operative enterprises found in him a zealous promoter, and with the great Zone Catalogue of the Astronomische Gesellschaft his name will always be associated.

The double stars of Otto Struve were naturally of a more difficult class than those of his father, the instruments being respectively a 15-inch and a 9·6-inch. The measures were collected and discussed by Professor Hussey in 1900. One of his stars, δ *Equulei*, has the shortest period (5·7 years) of any known visual binary. An interesting feature of Struve's work was his unusually large personal equation in the measurement of position angles of double stars; by experiments with artificial stars he was enabled to deduce satisfactory formulæ for correction.

A discussion of the measures of *Saturn's* rings, in which he introduced the nomenclature now used, led him to the conclusion that the inner ring is approaching the planet. This has not been confirmed by more recent measures.

In 1873 he was elected a Foreign Member of the Royal Society.

In 1889, on the fiftieth anniversary of the foundation of Pulkowa Observatory, he retired from the directorship, to which Bredichin was then appointed. The remainder of his life was spent at St. Petersburg, and latterly at Karlsruhe.

Struve died on the 14th of January 1905. He had been twice married, but his second wife predeceased him by some years. The astronomical tradition of the Struve family is worthily maintained by his son, Dr. Hermann Struve, who is an Associate and Gold Medallist of the Society.

Pietro Tacchini was born in 1838 at Modena. He graduated as a prizeman in Engineering at the Academy of Modena, and afterwards studied astronomy at the Observatory of Padua. At the early age of twenty-one years he was called to take

charge of the Observatory of his native city, but four years later left this position on being appointed to the staff of the Palermo Observatory. In 1879 he became Director of the Observatory of the Roman College and of the Central Bureau of Meteorology, and in this office he was for many years one of the central figures in Italian astronomy and spectroscopy. His principal interest was in solar physics; observations of the Sun were carried on regularly during practically the whole period of his scientific activity, and for thirty years he organised Italian eclipse expeditions as opportunity offered. He was one of the chief founders of the Società degli Spettroscopisti Italiani in 1872, and edited its *Memorie*, in which much of his own work was published.

In 1873, writing on the connection between solar prominences and the Aurora Borealis, he stated that the relationship was closer between these phenomena than between Sun-spots and the Aurora.

In 1874 he observed the transit of *Venus* in Bengal, and from his spectroscopic investigations inferred the existence on *Venus* of an atmosphere similar to our own.

In 1883 he went with Janssen to Caroline Island to observe the total solar eclipse, and made the discovery of *white* prominences; this was confirmed in the 1886 eclipse, when Tacchini observed a white prominence 150,000 miles in height.

He was elected an Associate of the Royal Astronomical Society in 1883, and was awarded the Rumford Medal of the Royal Society in 1888. In 1891 he was elected a Foreign Member of the Royal Society, and in the following year received the Janssen Medal of the Paris Academy.

His work as Director of the Meteorological Bureau was carried on with great activity, and to him is due the establishment of the Italian forecasting service.

Tacchini died at Spilamberto, in the province of Modena, on the 24th of March 1905.

Proceedings of Observatories.

Royal Observatory, Greenwich.
(*Director, Sir William Christie, K.C.B., Astronomer-Royal.*)

Transit Circle.—During the year 11,405 observations of transits and 10,057 of meridian zenith distances have been obtained. The Sun has been observed 152 times and the Moon 115 times. The lunar crater Mösting A has also been observed 21 times. Reflexion observations of stars have been obtained on 75 nights. The observations of transits and zenith distances are completely reduced.

The observations for the Second Nine-Year Catalogue are completed. This catalogue will consist of two parts—(I.) Fundamental and zodiacal stars; (II.) Reference stars for the Astrographic Catalogue. Part I. will contain clock stars, polars, fundamental stars contained in the *Nautical Almanac* and other ephemerides, and 834 zodiacal stars given in the Appendix to the *N.A.* for 1897. Part II., which will be arranged in zones 1° wide, contains 10,050 stars. With only seven exceptions, five observations have been obtained of each of these stars, while six of the remainder have been observed four times each, and the seventh (*R Draconis*) is a variable star which has been observed three times, having been too faint for observation on other occasions.

From a comparison of the right ascensions observed above and below pole of the 1400 stars within 10° of the pole, it appears that the probable error of a star's position in this catalogue will be between $\pm 0''\cdot 20$ and $\pm 0''\cdot 25$ in arc of a great circle.

This catalogue furnishes a large amount of material for the determination of proper motions; in particular the comparison with Carrington's Catalogue for 1855 should be of great value.

The reductions for the catalogue are well advanced. The right ascensions of the clock stars and polars have already been determined, and the comparison made with the 12-hour groups. The positions of clock stars for 1906 will be based on the observations of the new catalogue. With the exception of the observations made in 1905—to which corrections for variation of latitude have yet to be applied—the annual results are entered on the catalogue sheets. Precessions and secular variations are all computed.

For the next Nine-Year Catalogue it is proposed to observe all the reference stars down to $9^{m}\cdot0$ in the Oxford Astrographic Zone, *i.e.* between the limits of 24° and 32° of north declination.

In view of the completion of one catalogue and commencement of another, observations have been made for pivot error and for the errors of the screws of the transit and zenith distance micrometers and of the microscopes. The object-glass has been removed to be cleaned and re-polished, and the instrument is being generally overhauled.

As a result of the re-reduction of Groombridge's observations now completed, Messrs. Dyson and Thackeray have discussed the proper motions derived from Groombridge's Catalogue compared with modern Greenwich observations and have deduced the value of the constant of precession and the direction of the solar motion in space (*M.N.* vol. lxv. p. 428).

Mr. Cowell's analysis of the Greenwich lunar observations 1750–1901 has now been completed by the discussion of the Moon's latitude from the Greenwich meridian observations 1847–1901, and he has deduced the coefficients for a hundred terms in latitude.

In connection with this work Mr. Cowell has discussed the data given by ancient solar and lunar eclipses, and has deduced important conclusions in relation to the secular accelerations of the Moon and Earth (*M.N.* vol. lxv. p. 867, and vol. lxvi. pp. 3–7).

Altazimuth.—This instrument has been used as a reversible transit-circle for observation of the Sun, Moon, planets, and fundamental stars, 1326 observations of right ascension and 1179 of north polar distance being obtained. The crater Mösting A has been observed 41 times. The observations of transits of this crater will serve to connect the observations of first and second limbs made before and after full respectively, and the observations of zenith distances will, in combination with similar observations being made at the Cape, serve to determine the parallax of the Moon.

In the first and last quarters the instrument has been regularly used for extra-meridian observations of the Moon. During the year 34 extra-meridian observations of the Moon have been obtained, and 67 meridian observations of the limbs.

Reflex Zenith Tube.—During the year 799 double observations and 30 single observations have been obtained, the brighter stars having been observed over as long periods as possible. *γ Draconis* was observed on 62 days, *β Draconis* on 40 days, *ι² Cygni* on 41 days and *θ Ursæ Majoris* on 23 days. The observations are completely reduced to 1905 October 31, and copy for press prepared to 1905 August 4. Ledgers of the observations from 1902 to 1904 December 31 have been prepared. The hitherto unpublished observations made from 1886 to 1899 have been prepared for press and will be printed as an appendix to the volume for 1904, with a brief summary of the observations made from 1883 to 1885 to discover a possible temperature effect in the observations.

Equatorials.—Fifty-one separate occultation phenomena of disappearance or reappearance have been observed by one or more observers.

28-inch Refractor.—As in 1904 the weather has been unfavourable for the observation of close and difficult double-stars, and in the absence of the good definition required for these stars, the measurement has been continued of those stars of Struve's Mensuræ Micrometricæ which have been neglected.

An analysis of the observations gives :

46	stars of	distance	$<0''\cdot5$
57	,,	,,	$0''\cdot5$–$1''\cdot0$
81	,,	,,	$1''\cdot0$–$2''\cdot0$
249	,,	,,	$>2''\cdot0$

Amongst the stars observed are *κ Pegasi* (10 nights), *δ Equulei* (13 nights), 70 *Ophiuchi* (12 nights), and *Procyon* (1 night).

The following table gives an analysis of the stars observed since the beginning of double-star observing at the Observatory in 1893 :—

Separation.

	<1″.	1″–3″.	3″–5″.	>5″.		<1″.	1″–3″.	3″–5″.	>5″.
1893	38	56	14	13	1900	215	113	19	23
1894	8	9	2	2	1901	226	125	22	34
1895	60	52	12	21	1902	166	114	21	32
1896	106	78	14	23	1903	195	135	40	72
1897	125	78	13	21	1904	140	200	91	189
1898	137	96	21	35	1905	103	134	65	131
1899	260	174	32	68					

The stars originally selected for observation were those with orbital or suspected orbital motion, and were chosen principally from the Catalogues of Struve, Otto Struve and Burnham, and a smaller number from Hough. For 1906 a new working catalogue has been prepared containing most of the double-stars discovered by Hough together with a number taken from the Catalogues of Struve, Otto Struve, Burnham, Hussey and Aitken.

Thompson Equatorial.—With the 26-inch refractor 51 photographs of *Neptune* and its satellite have been obtained on 25 nights.

With the 30-inch reflector a series of photographs of the sixth and seventh satellites of *Jupiter* was begun on August 23 and is still being continued. Up to December 31, 46 photographs of *J.* vi. had been obtained on 25 nights, and 15 of *J.* vii. on

12 nights. Photographs of comets have been taken in the year 1905 as follows :—

Comet *e*, 1904,	11	photographs on	11 nights
Comet *a*, 1904,	12	„ „	11 „
Comet *a*, 1905,	12	„ „	10 „
Comet *b*, 1905,	12	„ „	7 „
Comet *c*, 1905,	5	„ „	3 „

75 photographs of 31 minor planets have also been taken.

These photographs are all taken for determination of position.

A few photographs of nebulæ have also been taken, of which the most successful is one of H V. 14 *Cygni*, with an exposure of 105^{m}.

As regards the measurement of photographs and reductions, the first half of the year was taken up with the 198 astrographic and 152 Thompson photographs of *Eros*. These were completed and the results sent to M. Loewy on August 3.

The results of preliminary measures of *J.* vi. and *J.* vii. were communicated to the Society in November. A more complete measurement and discussion of these photographs has been begun.

The photographs of *Neptune* and its satellite are measured and discussed as far as the end of the last opposition.

Owing to the *Eros* work, the measurement and reduction of the photographs of comets and minor planets had fallen into arrears since 1903. The comet photographs have all been measured with the exception of 1905 *c*, which is still under observation. The results have been published for Comets 1902 *d*, 1903 *a*, 1904 *b* (Encke), and 1905 *c*, and considerable progress has been made with Comets 1903 *c*, 1904 *a*, 1904 *e*, and 1905 *a*. The measurement and reduction of the photographs of minor planets have been commenced.

Experimental photographs of spectra of Sun-spots were taken last autumn with the spectroscope attached to the 30-inch reflector, a diffraction grating being used in conjunction with a direct-vision half-prism to give an extended scale for measurement of the widening of Fraunhofer lines. It is proposed to take further photographs under improved conditions in the spring, when the Sun's altitude will be again sufficient for the purpose.

Astrographic Equatorial.—Work with this instrument has been in the main confined to replacing chart-plates, which, though satisfactory in other respects, are, owing to slight photographic defects, unsuitable for production of enlarged prints. During the year 115 chart-plates, 13 catalogue-plates, 13 plates of the field round *Jupiter*, and 12 plates for adjustment of the instrument have been taken. Of the chart-plates 27 were rejected, principally because they did not come up to the standard in showing faint stars.

The measurement of the photographs was completed by May 10, the total number of plates measured in the year being 22, containing 9550 pairs of images. Since May 10 remeasures of discordant observations in Zones 80°–84° and of some additional reference stars (outside the ordinary limits of measurement) have been made, completing the work as far as Dec. 85°.

The measures of half of Zone 74° and of Zones 75°–79°, covering 438 square degrees, have been printed during the year. The measures are now printed as far as Dec. 80° and occupy 663 pages of vol. ii.; the remainder, covering 310 square degrees, will probably be printed in about half a year's time, and will thus complete this part of the Greenwich Section of the Astrographic Catalogue. Copy for press is prepared for Zones 80°–83°, and the computations for Zones 84°–86° are in hand.

The counting of the chart-plates is now complete to the end of Zone 77°, 267 plates having been counted during the year.

Enlarged reproductions of the chart-plates have been made for 198 plates during the year. The total reproduced to December 31 is 325 plates, the three Zones 65°, 66°, and 67° being complete, and Zones 68°, 69°, 70° nearly half finished.

Photoheliograph.—Photographs of the Sun have been taken on 173 days with the Thompson (9-inch) photoheliograph, and on 51 days with the Dallmeyer (4-inch) during the time that the Thompson photoheliograph was dismounted for use in the eclipse expedition to Sfax, Tunisia. Of the photographs taken 541 have been selected for preservation. Photographs have been received through the Solar Physics Committee from Dehra Dûn, India, up to 1905 December 13, and these have been further supplemented by photographs from the Royal Alfred Observatory, Mauritius, and from the Observatory at Kodaikánal, India. In all only two days are still unrepresented in the year ending 1905 December 13, and one of these will probably be eventually supplied. The last photograph received from Kodaikánal is dated 1905 September 26, and the last from Mauritius 1905 June 30. The photographs from these two observatories are all measured, those from Dehra Dûn are measured up to 1905 November 26, and those taken at Greenwich to 1905 October 19. The increase of solar activity during the year has been very marked, and the work of measurement in consequence has been very heavy.

Some years ago solar photographs were received from the Observatories of Harvard College and of Melbourne, to supplement those of the Greenwich series for the years 1874 to 1877. The reduction of these measures has been completed during the past year; and the results, combined with those from the measures of the Greenwich photographs, have been passed for press, in the form both of a daily register of the Sun's surface and of a ledger of the spot-groups. The ledger of spot-groups for the eight years 1878 to 1885 is also being prepared for press, and it is

intended to publish the results for the whole twelve years as an appendix to the Greenwich results for 1904.

The photoheliographic results for 1904 have been passed for press.

Eclipse Expedition.—Funds having been provided by the Admiralty, a party consisting of the Astronomer-Royal, Mr. Dyson, and Mr. Davidson went out from the Royal Observatory to Sfax in Tunisia to observe the solar eclipse of August 30. They were generously assisted in the work by Professor Sampson, Mr. J. J. Atkinson, and Captain Brett, and successful photographs of the Corona and its spectrum were obtained. A preliminary account of the observations was given at a joint meeting of the Royal and Royal Astronomical Societies on October 19, and is printed in the *Proceedings of the Royal Society*, vol. lxxvii.

At the invitation of the Canadian Government, Mr. Maunder joined their party in Labrador for observation of the eclipse; but unfortunately, owing to cloudy weather, no results were secured.

Printing.—The volumes of Greenwich Observations 1903, and the New Reduction of Groombridge's Catalogue are ready and will be distributed shortly, together with the volume of Longitude Determinations, 1888-1902, which is printed and now being bound. The printing of the volume for 1904 is approaching completion. The Heliographic Results 1874–1885, completed from photographs supplementing the Greenwich series, are being printed as a special publication, and the printing is completed to the end of 1877. The printing of vol. ii. of the *Astrographic Catalogue*, which completes the measures of the Greenwich section, is finished as far as Zone 79°, more than five-sixths of the whole being thus done.

The Observatory has lost the valuable services of Mr. Dyson, who resigned his post as Chief Assistant on his appointment as Astronomer-Royal for Scotland and Professor of Astronomy in Edinburgh University. His resignation took effect on 1906 January 13, just after the date of this report.

Royal Observatory, Cape of Good Hope.
(*Director, Sir David Gill, K.C.B., H.M. Astronomer.*)

The new transit circle has been in active operation during the year, the transits having been observed by the Repsold travelling wire method and without clockwork to aid the observer.

Experiments, however, have been made with the cone apparatus constructed by the Société Génevoise to the designs of H.M. Astronomer, but the method has not yet been brought into regular use, as the original motor, employed to rotate the cone, required modification to give perfect results. The cone

apparatus itself works to perfection, but it was found undesirable to apply the observer's fingers to the revolving drum of the micrometer, and the improved motor will be provided with differential gear like that employed on the driving gear of an astrographic equatorial, so that the motion of the wire can be accelerated or retarded by simply touching one of two keys held in the observer's hand, and without touching the revolving micrometer drum. The transit circle was reversed on its bearings every Monday morning, and the object glass and eye-end were exchanged at the conclusion of the observations of 1905.

The outer chamber enclosing the case of the new sidereal clock has been completed and has proved most successful. The temperature within the clock-case is now maintained constantly at 75° F. within a tenth of a degree F.

Some trouble has been given by demagnetisation of the polarised armature of the magnet which discharges the pendulum of the slave clock, but this difficulty seems now to have been overcome.

The driving sector of the Victoria Telescope, which had been sent for repair to Sir Howard Grubb early in November 1904, was received in April 1905, together with a "quick slow-motion" in R.A. devised by him, which is of great convenience for rapidly bringing a star on the slit of the spectroscope. The instrument was brought into use on May 4.

Some desirable changes had to be made on the spectroscope; these occupied a long time, as only one mechanic is available and his time was much taken up in connection with the transit circle, the mounting of the underground object-glasses, &c.

The Victoria Telescope was devoted to the photographing of star clusters and nebulæ, and photographic observations of the satellites of *Uranus* and *Saturn*. A number of good photographs of *Phœbe* have been secured. An unsuccessful search was made on six nights for Comet Tempel III.; Comet *b* 1905 was observed on two nights. Fifty-four star-spectra have been measured and discussed for motion in the line of sight.

The object-glasses for use in the collimator pits of the new reversible transit circle have at last been received of the requisite foci and good definition; they are now mounted and have been under observation since October 31.

It is found that by their means the reflex images of very small illuminated discs (attached to the slides that carry the lenses of 300 feet focus and the marks in focus of these lenses) can be adjusted by a single pointing to coincidence with a wire fixed on the same slides, with a probable error of less than $\pm 0{\cdot}005$ mm., so that the probable error in this adjustment of the points of azimuth-reference barely exceeds $0''{\cdot}01$.

The marks, when so adjusted, retain a perfectly constant relative azimuth far within the probable error of their observation with the transit circle; but without adjustment over the optical centres of the underground object-glasses there would be

comparatively large variations of azimuth, as is proved by the readings of the scales attached to the slides. In the case of the south marks this reading has changed with a steady increase by 1·47 mm. between October 31 and December 31, that of the north mark by 0·99 mm. in the same period. The readings of the scales, which carry the long focus lenses, are much more constant, the extreme readings having varied only 0·07 mm. for the north lens and 0·08 mm. for the south lens in the same period.

The reductions of the observations of Circumpolar Stars are not yet sufficiently advanced to determine the absolute azimuth variation of the underground marks. There is evidence, from discussion of the observations of the marks, of a systematic variation of the azimuth of the transit circle itself between sunset and midnight, and always in the same direction, amounting from 0″·3 to 0″·5.

The printing of the Cape Catalogue of 8560 stars (Photographic Zone Standards) has been completed. The introduction has been sent to the printers.

The manuscript of separate results of Meridian Observations 1900–04, all reduced to the Equinox 1900, was sent to the printers on 1905 June 20. The sheets have been passed for press to R.A. 19^h.

The manuscript of the Catalogue of 4360 stars, including 2798 selected zodiacal stars and all stars brighter than 8·1 magnitude which are not contained in Gould's General Catalogue (excepting those in the zone −40° to −52°, most of which are included in the Astrographic Standard Catalogue), has been sent to the printer and some of the first sheets passed for press.

The manuscript of the Solar and Planetary Meridian Observations 1884–92 is ready for the printer.

The manuscript of vol. x. of the *Annals*, containing researches by Mr. Lunt on the spectra of silicon and fluorine, has been sent to the printer.

The printing of part ii. vol. xii. of the *Annals*, containing Mr. Cookson's observations with the heliometer of the relative distances and position angles of *Jupiter's* satellites, and his derivation from them of the mass of *Jupiter* and of the inequalities of the motions of the satellites, is nearly completed.

The manuscript of the results of the heliometer observations of major planets from 1897 to 1904 is nearly ready for the printer.

The old transit circle has been employed at the urgent request of Professor Boss to determine the positions of 1154 stars south of Dec.−36°, of which he is specially desirous to obtain observations in connection with the completion of his Standard Catalogue. Stars of which occultations have been observed or which have been employed for latitude determination in connection with the geodetic survey are also included in the working list with the old transit circle.

The new reversible transit circle has been devoted to the observation of standard stars.

In co-operation with the Royal Observatory, Greenwich, the zenith distance of the Moon has been observed with both transit circles for determination of lunar parallax.

The following observations have been secured :—

	Old T.C.	Reversible T.C.
Number of transits	2679	4199
Determinations of z. d.	1718	4236
Collimation, by collimators	64	24
„ „ reflection and reversal	0	42
Level	225	364
Azimuth	252	433
Observations of azimuth marks N. ...	0	298
„ „ „ S. ...	0	293

These observations include 51 observations of the lunar crater Mösting A made with the old transit circle and 25 with the new reversible transit circle.

Of occultations there have been observed :—

Disappearances at the dark limb	15
Reappearances „ „ „	4
„ „ bright limb	1
	20

The following oppositions of major planets have been observed with the heliometer during the year :—

	No. of Observations.	No. of Nights.
Opposition of *Mars*	... 48	4
„ „ *Uranus*	... 60	6
„ „ *Saturn*	... 43	7
„ „ *Jupiter*	... 51	8
„ „ *Neptune**	... 20	3

The following heliometer observations have been made during the year in connection with the triangulations of the comparison stars :—

	Observations.
Neptune 1897–1904, *Jupiter* 1906	122
Mars 1899...	110
Mars 1905...	74
Uranus 1898–1902	22
Jupiter and *Saturn* 1901...	29
Jupiter 1902, *Saturn* 1903	36
Saturn 1902	40
Jupiter 1904	42

* Still under observation.

The triangulations of the comparison stars for *Neptune* 1897–1904, *Jupiter* 1906, *Uranus* 1901–2, *Jupiter* and *Saturn* 1901, *Mars* 1899, and *Jupiter* 1904 are now completed.

A special series of observations with the heliometer was made by Mr. Bryan Cookson during the visit of the British Association to South Africa, to determine whether, in his measurements, distances like those mutual distances of *Jupiter's* satellites which chiefly enter into the determination of the mass of *Jupiter* have any systematic error when compared with distances like those of the standard stars employed for determining the scale value. For this purpose sets of three stars were selected, such that in each set the three stars lie nearly on the same great circle at distances varying in proportion from about 1 : 7 to 1 : 14. If the sum of the two measured distances when projected on the great circle joining the extreme stars (about 110′) is equal to that of the distance measured directly between the two extreme stars, then the systematic error of the measured distances on which the determination of the mass of *Jupiter* depends should be zero—or at least should be affected by no "distortion error."

Mr. Cookson secured 302 observations of this kind. The position angles of these stars (227 observations) were measured by Mr. Whittingdale after Mr. Cookson's departure for England, and the results show that Mr. Cookson's measures of distances from about 500 "to 1000" are not affected by any sensible systematic error.

With the astrographic telescope the following work has been accomplished :—

	No. of Plates.	No. of Exposures.	Duration of Exposure.
			m m m
Triple exposure chart plates, passed ...	77	231	20 20 20
,, ,, ,, ,, rejected...	5	15	20 20 20
			m
Single exposure chart plates, passed ...	85	85	30
,, ,, ,, ,, rejected...	3	3	30
			m m s
Catalogue plates, second series, passed	188	564	6 3 20
,, ,, ,, ,, rejected	44	132	6 3 20
Adjustment plates	19	...	various
Plates for Mr. de Sitter *	13	52	1m and trail
Miscellaneous †...	10	...	various

* Taken in connection with discussion of photographs of *Jupiter's* satellites 1904.

† The miscellaneous plates include 5 plates near *Jupiter*, 2 plates of region near Comet *b* 1905, and 2 plates of occulted stars.

The following table gives the work done in connection with the Astrographic Chart and Catalogue to the end of 1905 :—

Dec. of Centre of Zone.	Triple Image Charts.		Single Image Charts.		Second Series Catalogue Plates.	
	Taken.	To be Taken.	Taken.	To be Taken.	Taken.	To be Taken.
41°	143	1	...	...	144	0
42	...	...	142	2	144	0
43	144	0	...	...	143	1
44	...	...	140	4	144	0
45	143	1	...	...	143	1
46	...	...	143	1	143	1
47	144	0	...	...	143	1
48	...	...	142	2	144	0
49	118	2	...	...	119	1
50	...	...	119	1	120	0
51	119	1	...	...	120	...
52	...	...	65	55	...	...

During the year 148 Catalogue plates, containing images of 1944 standard and 112,086 other stars, have been measured ; all stars have been measured in reversed positions of each plate, and all standard stars have in addition been measured by two observers. Besides these 16 plates of the first Catalogue series were measured for Professor Kapteyn, for purposes which were the result of some discussions with him at the Cape on the occasion of the visit of the British Association.

The actual state of measurement on December 31 is as follows :—

Zone.	No. of Plates Measured.			Copied for Press.		
	Before 1905.	During 1905.	Un-measured.	Before 1905.	During 1905.	Out-standing.
−41°	144	...	...	144	...	0
−42	137	7	...	128	16	0
−43	139	3	2	70	45	29
−44	118	14	12	43	24	77
−45	108	30	6	18	1	125
−46	71	42	31	2	1	141
−47	24	41	79	0	2	142
−48	18	7	119	4	1	139
−49	0	1	119	0	1	119
−50	0	3	117	0	3	117
−51	0	0	120	0	0	120
Totals	759	148	605	409	94	1009

The total number of measured plates is now 907, containing

over 550,000 star images, corresponding to about 251,000 different stars.

The constants for zones whose centres are −41° and −42° have been computed, and also for 104 plates of zone −43°, for 16 plates of zone −44°, and 19 plates of zone−45°.

Colonel Morris reports that the field work of the principal triangulation of the Transvaal and Orange River Colony is now completed. It is expected that the reduction of the observations will be finished by the end of 1906. A detailed account of the work was presented in a Report to Section A of the British Association and will be published in full in the British Association Report of the 1905 meeting.

The latest Report of the Geodetic Survey of Rhodesia from Dr. Rubin gives copies of field work up to 1905 August 5, and shows that stations up to latitude −13° 58′ have been observed.

The Report of the Anglo-German Boundary Commission has been completed and sent to press.

Longitude of Accra.—Signals for longitude were exchanged, through the West Coast cable, on five nights in February 1905, between Mr. R. T. Pett at the Cape and Major (now Lieut.-Col.) A. E. Watherston, C.M.G., R.E., at Accra. Good time determinations were obtained on four of these nights. The following are the results for longitude :—

	h m s	s
Accra, W. of Cape T. C.	1 14 44·309	±0·019
Cape T. C., E. of Greenwich ...	1 13 54·757	±0·084
Accra, W. of Greenwich	0 0 49·552	±0·086

Current time, 1ˢ·48 ; length of cable, 3648 knots.

Longitude of Swakopmund.—Two German military officers, Captain Füsslein and Ober-Leutnant von Stephani, who were engaged upon the determination of the longitude of Swakopmund, were provided with accommodation for their instruments at this Observatory.

Longitude of St. Helena.—With the concurrence of the hydrographer and the kind co-operation of the Union-Castle S.S. Company, who carried the travelling observer to and from St. Helena free of charge, a telegraphic determination of the longitude of St. Helena was made in September and October by Messrs. Pett and Cox—Mr. Pett at St. Helena and Mr. Cox at this Observatory.

Good time determinations were obtained on six nights. The resulting longitude is as follows :—

	h m s	s
Johnson's Observatory, W. of Cape Transit Circle	1 36 48·022	±0·023
Cape T. C., E. of Greenwich ...	1 13 54·757	±0·084
Johnson's Observatory, Ladder Hill, St. Helena, West of Greenwich	0 22 53·265	±0·087

Current time, 0ˢ·237 ; length of cable, 1881 knots.

For all these operations the use of the various cables was freely granted by the Eastern Telegraph Company.

The records of the seismograph have been regularly forwarded to Professor Milne, Secretary to the Seismological Committee of the British Association. A second copy is also forwarded to the Consul-General for Germany, Cape Town for transmission to the central station for investigation of earthquakes at Strassburg.

The meteorological observations have, as usual, been communicated to the Meteorological Commission, Cape Town.

During the visit of the British Association to Cape Town many of the members availed themselves of the opportunity of inspecting the Observatory and its equipment.

Royal Observatory, Edinburgh.
(Director, Prof. F. W. Dyson, Astronomer Royal for Scotland.)

During the past year the Observatory has suffered the loss of its distinguished Director, Professor Ralph Copeland, Ph.D., who died on 1905 October 27. Mr. F. W. Dyson, Chief Assistant at the Royal Observatory, Greenwich, has been appointed to succeed him in the Directorship of the Observatory and in the Chair of Astronomy at the University of Edinburgh.

Meridian Circle.—The observations of zodiacal stars and heliometer comparison stars begun in 1898 have been continued by Mr. Clark throughout the year, with the exception of June and July, when zodiacal work is practically impossible in this latitude. The number of transits observed is 1088 and of zenith distances 907. Occasional observations of the planets have also been made.

15-*inch Equatorial.*—Micrometric observations of the position of Comet 1905 *a* were made on four nights in April, of Comet 1905 *b* on five nights in November, and of Comet 1905 *c* on four nights in December and January.

Spectroscopic Observations of the Rotation of the Sun.—These observations were made as in previous years on all suitable occasions by Dr. Halm. The observations from 1901–1905 have been discussed with the view of discovering the displacements due to the diurnal and annual motions of the observer with very satisfactory results, the eccentricity of the Earth's orbit, for example, being given within 4 per cent. of its true value. These investigations, which are being published in the *Proceedings* of the Royal Society of Edinburgh, need only be referred to here as evidence of the accuracy of the observations and their freedom from systematic error.

The reduction of the meridian observations has fallen somewhat into arrear. The observations from 1898–1901 have been reduced as far as apparent place, and the reduction to mean place will be completed in a few months. For the years

1902–1905 the chronograph tapes have been read. It is proposed to push on these computations as rapidly as possible.

The printing of Henderson's Catalogue for 1840, re-reduced under the charge of Dr. Halm, is nearly completed. The Introduction has been written but is not yet printed.

Seismographic observations have been made continuously by Mr. Heath and reported to the Seismological Committee of the British Association.

Meteorological observations have been regularly made.

Greenwich mean time has been supplied daily to Edinburgh and Dundee.

Cambridge Observatory (*Director, Sir R. S. Ball*).

Sheepshanks Equatorial.—During the year 73 plates, each containing four or more exposures, have been taken by Mr. Hinks. The greater part of these are in continuation of the stellar parallax series begun two years ago. A general description of the methods of this research has been published by Mr. Hinks and Mr. Russell (*Monthly Notices*, 1905 June, lxv. 775), and the first results, the parallaxes of Lalande 21185 and γ *Virginis* were published by Mr. Russell at the same time (*Monthly Notices*, lxv. 787).

Mr. Russell left Cambridge in 1905 July, but will continue the measurement and reduction of these plates at Princeton, N.J.

Experiments were made during the year to compare the speeds of various brands of ordinary and isochromatic plates with the photo-visual objective. The result was that the ordinary plate, utilising chiefly the blue and violet rays, was found to be more effective than the colour-sensitive plates, utilising nearly the whole range of photographic and visual rays brought to focus by the photo-visual objective.

Mr. F. J. M. Stratton, B.A. (Caius College : Isaac Newton Student in the University), has recently joined the Observatory as an honorary member of the staff, and has undertaken researches in the determination of the proper motions of faint stars by photography.

Meridian Circle.—The principal work of the year in this department has been the completion by Mr. Hartley of the preparation for press of a large volume of meridian circle results for the years 1872–1900. This volume will contain the results of all the individual observations for the Cambridge zone of the Astronomische Gesellschaft Catalogue, and in addition the results of about 12,000 observations of stars in the zone which were not included in the original programme, but of which a single observation had been made and published in the Zone Catalogue.

Observations of 631 stars in Gill's Zodiacal Star Catalogue

were made by Mr. Hartley on 26 nights, with the necessary observations of fundamental stars and instrumental errors. The reductions to apparent place are complete to 1905 July 31 ; and the reductions to mean place to 1905 June 22.

Floating Zenith Telescope.—Mr. Cookson has continued throughout the year the determination, with his floating zenith telescope, of the Constant of Aberration by Küstner's method, and of the variation of latitude. Observation of the two star groups in 1905 February and March was much interrupted by bad weather, but since then the weather has been fairly good, and at least six observations of each pair of star groups have been obtained. All the plates so far exposed have been measured, the refractions and daily corrections have been computed and checked, and it is expected that it will be possible to deduce a value of the Constant of Aberration from the first year's observation at the end of next April.

Reduction of Photographs of Eros.—The results from the 106 Cambridge photographs which were used in the experimental determination of the solar parallax published in 1904 June have been further reduced to apparent place and compared with the corrected Paris ephemeris. The results of 55 Oxford photographs have been similarly reduced at Cambridge. They will be published in detail in the twelfth Paris *Circular*, now in the press. The introduction to the Cambridge section will contain a brief summary of much work done during the year on the comparison of different ephemerides of the planet.

The discussion of all published photographic places of *repère* and comparison stars, for the investigation of the systematic errors of the different series, and the formation of a catalogue of standard star places, has made good progress, and an account of it is in preparation. Mr. Hinks has been aided in this work throughout the year by Miss Julia Bell, and a portion of the expense has been borne by a Royal Society grant.

Instruction.—Courses of instruction in practical astronomy, and in field astronomy and surveying, have been given by Mr. Hinks during the year.

The Newall Telescope, Cambridge Observatory.
(*Mr. H. F. Newall.*)

The Newall Telescope was used for observations on fifty nights in the first half of the year 1905 to June 30 ; after this date, partly because of change of programme of work and partly for reasons connected with a change of assistant, the record is no longer serviceable for comparison with previous years.

Spectroscopic studies of the stars have been carried on, principally in the determination of velocity in the line of sight. Eighty-seven photographs of stellar spectra, with terrestrial comparison spectra, were obtained by Mr. H. J. Bellamy before he left

the Observatory on June 30 to take up new work at the Royal Naval College at Osborne. In the first quarter of the year the four-prism spectrograph was used for continuation of the photographic study of stellar spectra in the green region of the spectrum. On March 22, when the desired material for these studies was collected, it was readjusted for the region near $H\gamma$, and was used in that adjustment until July 21, when it was dismounted to be packed for use in observations of the total solar eclipse on August 30 at Guelma, in Algeria. It was received back again at the Observatory on September 27, and since that time the prism train has been used by Mr. E. T. Whittaker in the study of the red region of certain terrestrial spectra by photographic methods.

A description of the four-prism spectrograph as used for stellar studies was given in the *Monthly Notices* last year (*M.N.* lxv. 636–650). And the results of determination of velocity for stars observed in 1903, in co-operation with observatories abroad, have also been published (*M.N.* lxv. 651–655); those for 1904 are being prepared for publication.

In the autumn a new grating spectrograph was mounted on the 25-inch equatorial. It was designed (i.) to give serious trial to a comparison of the efficiency of grating and prisms in stellar studies, on the lines indicated in a discussion of the design of large spectrographs (*M.N.* lxv. 608–635), and (ii.) to test the atmospheric conditions at Cambridge for solar work. Up to the present date it has been used only in observations of sun-spot spectra, and a good deal of preliminary work has been done, specially in connection with the study of the relative brightness of (*a*) the spectrum of the umbra of large spots, and (*b*) the spectrum of the glare of the sky close to the limb of the Sun. Fifty-six photographs have been kept for detailed study, out of a great many taken in this connection.

If one may judge by the distinctness with which many of the peculiarities of sun-spot spectra are recorded on the photographs obtained in these unfavourable months, and by the clearness with which the resolution of the spectrum of the umbra into fine lines and bands, as recorded by Young, Dunér and others, has been corroborated on many occasions, these preliminary observations show that the atmospheric conditions at Cambridge for the study of solar phenomena are promising.

Observations of the total eclipse of the Sun on August 30 were successfully made at Guelma under very favourable conditions of weather. A preliminary report upon them was published in the *Proceedings of the Royal Society* (vol. lxxvii. 56–76).

Mr. W. H. Manning began work at the Observatory in June in place of Mr. H. J. Bellamy, who left on June 30.

Dunsink Observatory.

Systematic work with the meridian circle recommenced in October last, when it was decided to re-observe the stars in Part IV. of *Dunsink Observations*. This is a list of 321 red stars by Dr. Dreyer. During the year 1905 the number of observations made with this instrument is 1067, consisting of 357 observations in R.A. of red stars, 170 observations of Berliner Jahrbuch stars for clock correction, 29 determination of level, 28 of collimation, while 23 stars were observed for azimuth errors. In declination 357 observations were made of red stars, 80 stars were observed for the equator point of the circle, 18 determinations were made of the nadir point, and 5 of the error of runs.

The first part of the year was occupied in finishing the reductions of Sir David Gill's zodiacal stars and preparing the work for press ; this work is now ready for the printer.

In September a hole was made in a thick pier in the basement of the observatory, and the Dent Sidereal clock was taken from the meridian room and placed there. The temperature in this place is more uniform than the meridian room, the variation in a week being about 1° ; the rate of the clock consequently shows a great improvement.

Some photographs were taken with the Roberts telescope, but owing to a slight shift of the mirror during long exposures they are found to be useless.

The South Equatorial has principally been used in showing visitors objects of interest on the first Saturday of each month.

The time service with Dublin has been carried on as usual.

Since the date of this report the death has been announced of Professor C. J. Joly, M.A., Sc.D., F.R.S., Royal Astronomer for Ireland. A notice will be found in the Obituary.

Durham Observatory. (*Director, Professor R. A. Sampson.*)

During the year the almucantar has been used on forty nights, and 619 transits have been observed with it and reduced.

A very large amount of work has been done on the discussion of the Harvard eclipses of *Jupiter's* satellites. The work is now almost complete as far as concerns the derivation of the elliptic elements of the orbits, the chief inequalities of the four satellites, the position of *Jupiter's* equator, the equation of light, and other quantities involved in the theory. When this work has been written out for publication in the Harvard *Annals* it is intended to proceed with the formation of a new theory of the motions based upon the elements determined.

Glasgow Observatory. (*Director, Dr. L. Becker.*)

The observations of stars close to the Pole were continued with the transit circle during the first four months whenever the sky was sufficiently clear. The spectrograph connected with the 20-inch reflector was principally employed on attempts to photograph the red and yellow portion of the spectra of planets. A series of fairly good negatives of *Jupiter's* spectrum was secured, but it is hoped that with a longer exposure still better results might be obtained. Unfortunately the weather was not more favourable to the experiment than in former years, yielding only twenty-eight hours on six nights from October 1 to December 31.

The site of the observatory has in the course of years become unfit for an observing station. According to regular observations begun four years ago on the distance at which objects can be seen from the Observatory the radius of visibility is, in the four months November to February, less than a mile on 70 per cent. of the occasions, and only on 5 per cent. of the occasions distant hills can be seen. The University Court has at present under consideration a scheme for the removal of the Observatory to a more favourable site outside the range of fog and haze which usually envelop this large manufacturing city.

A preliminary report of the director's solar eclipse expedition to Kalaa-es-Senam, Tunisia, has been published in the *Proceedings of the Royal Society*, A, vol. lxxvii. He successfully employed mechanisms governed by a clock which automatically effected the exposures and the changing of plates.

The time service and meteorological observations have been carried on as in former years.

Liverpool Observatory. (*Director, Mr. W. E. Plummer.*)

Reference was made in the last Annual Report to the measurement of a photograph of the cluster in *Hercules* taken with the large refractor of the Yerkes Observatory. A measuring machine kindly lent by the Oxford University Observatory has been used for this purpose. The results of the measurement and their discussion have been published in *M.N.* vol. lxv. 801–813, and arrangements are in progress for undertaking new work in the same direction. In addition to the ordinary work, which is carried on with the transit instrument, the equatorial has been employed as continuously as possible in the observation of comets, the results of which appear from time to time in the Society's publications. As in previous years, occasional observations of double stars are made.

The general maintenance of the Observatory is continued as in former years. No alteration is to be reported either in the

permanent staff or in the instrumental equipment. The meteorological and seismological observations are continuously maintained. In connection with the routine work may be mentioned the distribution of time signals, the testing and rating of chronometers, and the examination of sextants and other apparatus, for which the Mersey Docks and Harbour Board is prepared to grant certificates of test. Lectures in connection with the University of Liverpool are regularly given in the Observatory.

Radcliffe Observatory, Oxford.
(*Director, Dr. A. A. Rambaut, Radcliffe Observer.*)

Systematic work with the transit circle has been discontinued throughout the year, only occasional observations being made with it for the determination of time and instrumental errors. A recomputation of the division errors of the circle as determined in 1881 and 1882 was carried out, and in connection with this work a number of readings of the circle were taken for determining the errors of the four quadrantal lines 0°, 90°, 180°, and 270°. The result of this recomputation was to confirm very closely the division errors found by Stone, which have been used in the reduction of all zenith distance observations since 1880. Advantage was taken of the interruption of work with the transit circle to send the eight microscope-micrometers to Messrs. Troughton & Simms for cleaning and repairs.

The printing of the Catalogue mentioned in former reports has, with the exception of the introduction, been completed during the year. It is hoped that the introduction may be printed and the volume ready for distribution within a few weeks. This Catalogue gives the position of every star down to the seventh magnitude contained in the Zone 85° to 90° N.P.D., with very few exceptions, and these occur only in double or multiple systems. In it will also be found the position of every star in Dr. Downing's Zodiacal List which has not been already included in the Radcliffe Catalogue for 1890, with the exception of one star (D.M. + 27°, 725) whose magnitude, as given in the list, is obviously in error.

The places of the Catalogue have been compared with those of the Radcliffe Catalogue for 1890, the Greenwich Second Ten-Year Catalogue for 1890, Newcomb's Fundamental Catalogue, and the Albany (A.G.) Catalogue, 1875, with very satisfactory results. The probable errors in both co-ordinates are also very small, the probable error of a single observation being only $\pm 0^{s}\cdot 028 \times \operatorname{cosec}$ N.P.D. in R.A., and $\pm 0''\cdot 32$ in N.P.D.

The Barclay 10-inch equatorial has been used for various purposes, including observations of Mr. Stanley Williams's variable, 159 (1904) *Pegasi*, of Mrs. Fleming's Nova, 104 (1905) *Aquilæ*, the lunar crater *Linné*, and of the solar eclipse of August 29–30.

monthly-notices-of-the-royal-

The new double equatorial has been used during the spring and autumn months for investigating stellar parallax according to the method proposed by Professor Kapteyn (*Bulletin de la Carte du Ciel*, tome i. p. 262). In this work it is essential that the stars should be photographed close to the meridian, and also that the parallax factor should be as large as possible. To ensure these two conditions and at the same time to avoid running into twilight, the star must be observed within comparatively narrow limits of time, so that a spell of unfavourable weather may seriously interfere with the carrying out of the full programme. During the year nine parallax plates have been successfully completed, each containing twelve exposures—three in the first season, six in the second, and three again in the third—with three short additional exposures for identification. Seven plates have been exposed at two seasons—spring and autumn—and will, it is hoped, be completed in the ensuing spring. Sixteen plates have been exposed at only one season.

A number of plates, other than those taken for parallax, have been obtained in the course of the year. These include photographs of the *Pleiades*, *Præsepe*, the great clusters in *Perseus*, and Nova *Aquilæ*, &c., and plates taken for the adjustments of the polar axis, eyepiece scales, &c. The visual 18-inch telescope has been used for observations of Nova *Persei* (January 18 and October 4), Comet (*a*) 1905, and the lunar crater *Linné*. The partial eclipse of the Sun of August 29–30 was observed with the 7-inch telescope attached to this instrument (see *M.N.* vol. lxvi. 7).

A large number of measures, chiefly of an experimental character, have been made with the new photographic measuring-machine. In this instrument a microscopic *réseau*, optically projected on the plate and movable by two mutually perpendicular micrometer screws, is used for subdividing the 5 mm. spaces of the principal *réseau*. Great difficulty has been experienced in obtaining a *réseau* divided with sufficient accuracy for this purpose, and a considerable proportion of the measures made with the machine have been undertaken for the purpose of testing *réseaux* which have been subsequently discarded.

Meteorological and earth-temperature observations have been carried on as heretofore.

University Observatory, Oxford. (*Director, Prof. H. H. Turner.*)

The negotiations between the Government and the University concerning the printing of the Oxford portion of the *Astrographic Catalogue* were brought to a successful issue by the friendly aid of the Royal Society; and it was arranged last spring that the work should be done by H.M. Stationery Office, the expense being borne by the Government and the University in equal portions. At the request of the Director the commencement of

the printing was delayed until after the eclipse expedition, but as soon as possible after the return of the expedition detailed arrangements were completed, and the first proofs were received before the end of the year. The work of passing this Catalogue through the press will accordingly absorb a large part of the energies of the small staff of this Observatory for the next few years.

An expedition to Aswan, practically the eastern end of the line of totality, to observe the total solar eclipse of August 30 last was successfully carried out, with the able and generous help of Captain H. G. Lyons, Director of the Egyptian Survey, and his officers. The 13-inch astrographic objective was taken out to Aswan and mounted in a temporary tube of gas-piping and cloth, pointed to a 16-inch cœlostat. Mr. F. A. Bellamy obtained excellent photographs of the corona with it; and successful photographs in polarised light were obtained by the method of reflection from a plane glass surface suggested by Professor Schuster, two fine prisms being lent for the purpose by Mrs. McClean. The expedition was joined by Mr. J. H. Reynolds, of Birmingham, who took out to Egypt a reflecting telescope of 120 feet focal length, mounted with a cœlostat mirror of 28 inches aperture. Unfortunately his plates were not successful, in great part owing to the action of the wooden plate holders, which marked them badly with the wood pattern. The reasons why this occurred in this case and not in others are still uncertain, and are being made the subject of investigation.

The staff of the Observatory take pleasure in remembering that they were able to render some assistance to the successful Conference on Co-operation in Solar Research held in Oxford in September last.

Mr. F. H. Scragg, the last of the computers engaged from time to time for the measurement and reduction of the *Astrographic Catalogue* plates, left the Observatory in July last to take up an appointment at the Cape Observatory.

Temple Observatory, Rugby. (*Director, Mr. G. M. Seabroke.*)

The usual routine of instruction has been continued at this Observatory and the attendance has been good. Six boys have attended regularly for instruction in handling the instruments, and three have been sufficiently proficient to be allowed there alone to photograph the Moon and for other purposes. The measurement of doubles has been continued in spare time.

Solar Physics Observatory, South Kensington.
(*Director, Sir Norman Lockyer, K.C.B.*)

Observations of Sun-spot Spectra.—The Sun was seen on 241 days during 1905, and observations of sun-spot spectra were made on 125 days, permitting the examination of 268 spots in

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the region F—D. The records continue to show that the chief lines affected are due to vanadium, titanium, scandium, and some unknown elements.

Daily photographs (glass negatives) of the Sun's disc are received from Dehra Dûn (India) and Mauritius, the gaps in the Indian record being filled up as far as possible by negatives from Mauritius. The negatives are forwarded to Greenwich for measurement and reduction as they are required. Positives on paper are also received, and these are mounted on cartridge-paper and bound up into half-yearly volumes.

The Spectroheliograph.—The weather conditions were fine enough on 144 days to warrant attempts being made to obtain monochromatic photographs of the Sun. The instrument cannot be used satisfactorily during the winter months on account of its position. During the period 1905 February 2 to November 27 247 negatives were secured showing the distribution of "K" radiation on the Sun's disc; with the addition of an occulting disc over the primary slit-plate, 42 negatives were obtained showing the prominences round the solar limb.

A description of the instrument and details of the methods of working have been communicated to the Society (*Monthly Notices*, vol. lxv. pp. 473–486).

Stellar Spectra.—As several of the photographic instruments had to be dismounted and adjusted specially for the total solar eclipse, it was necessary to considerably modify the programme of night observations. Photographs of five stellar spectra for the green region were taken with the 6-inch prismatic camera, using one prism of 45°; six stellar spectra were obtained with the 9-inch prismatic reflector before its removal, and the 2-inch quartz-calcite prismatic camera has been further employed in photographing thirteen pairs of stellar spectra, under conditions as nearly constant as possible, for recording extensions of the continuous spectrum in relation to the position of the stars on the temperature curve of chemical classification. With the 36-inch reflector an excellent photograph of the spectrum of the *Orion* nebula was obtained in January, with an exposure of $3\frac{1}{4}$ hours.

Total Solar Eclipse, 1905 *August* 30.—The eclipse was observed at Palma, Majorca. Special preparations were made to secure large-scale spectrograms of the solar chromosphere and corona, and two of the chief instruments were the prismatic camera of 6-inch aperture, having an objective by Henry and three large objective prisms of 45° angle, and a prismatic reflector having a concave mirror of 12-inch aperture and 72 feet focus, with an objective prism of 10-inch aperture and 11° angle. Three coronagraphs of varying aperture and a large-scale "three-colour" camera were also employed. Observations of shadow bands, colours of corona, landscape, &c., meteorology, and various other eclipse details were made. Unfortunately the weather conditions were very unfavourable, and only a small

number of photographs were obtained, even these being through thin cloud, including prismatic spectra of the corona and prominences, and several fairly good pictures of the corona. Excellent records of the shadow bands were obtained.

Publications.—Various papers dealing with celestial and terrestrial spectra comparisons, stellar temperatures, arc spectrum of scandium, variations of meteorological changes of barometric pressure and rainfall, and eclipse results have been communicated to the Royal Society. Numerous papers are in progress dealing with these and allied matters.

Stonyhurst College Observatory. (*Director, Rev. W. Sidgreaves.*)

The meteorological and magnetical continuous records have been in good working condition throughout the year, excepting only the vertical force balance, which has been dismounted and has not yet been replaced by a better construction.

The solar surface has been observed on all possible days, and drawings made of spots and faculæ. These number 196 ; and the surface has not been observed free from spots.

The Rowland grating has been employed on the larger Sun-spots by eye observation of the red end of the spectrum, and by photographs of the green and yellow regions. But the instrument was dismounted in the spring of the year, to make room for experiments with a smaller Rowland grating and a concave reflector, preparatory to use on the solar eclipse. And we are indebted to the Royal Irish Academy for the loan of an excellent cœlostat (by Sir Howard Grubb), through the kind recommendation of a lamented friend, the late Professor Joly. Experiments with this apparatus have also added to our collection of Sun-spot spectra.

The eclipse expedition to Vinaroz, undertaken by Fr. Cortie, secured some valuable photographs of the solar corona ; but unfortunately the focus adjustment for the grating spectrograph for the "flash" was found to have had accidentally a wrong setting.

A larger cœlostat (15-inch mirror) has been kindly placed at our service by the Council of the R.A.S. ; and experiments are being made for the mounting of this in conjunction with one of the 15-inch reflectors of the late Colonel Cross, in order to take part more efficiently in the international programme of observations of Sun-spot spectra.

The stellar spectrograph has been employed on every available night. But only 212 exposures have been made, owing partly to the unfavourable weather and partly to the present impossibility of utilising the early morning hours.

Wolsingham Observatory. (*Rev. T. E. Espin.*)

The work of measuring double stars has been continued during the past year. A catalogue of neglected double stars in the zone +30° to +40° has been prepared and numbers 663 objects. Of these 154 have now been measured on one or more nights, and the results, as far as they are completed, presented to the Society. During the year sixty-six new pairs were found.

Mr. Franklin-Adams's Astrographic Laboratory.

As there has hitherto been no report of the work at this Observatory a preliminary memorandum will be necessary.

When it was started some ten years ago, at Machrihanish House, Argyllshire, the scheme of work proposed was to take such photographs of the Milky Way as would be original and available as valuable material for information as to star-distribution ; this scheme was, later on, extended to the charting of the whole heavens, north and south.

It was soon found that new lenses had to be designed. Whilst the first trial lens—6-inch aperture, F/4 focus—was being put through its preliminary tests in 1899, Professor Barnard, who was also seeking for a lens for a similar work, arrived in this country, came to the Observatory, and stayed for some time, making experiments and comparisons with a lens of his own ; he and Mr. Franklin-Adams then paid two visits to Messrs. Cooke & Sons, of York, with the result that a new lens was ordered with slightly different figuring and focus. Professor Barnard, on his return to the States, entrusted to American makers the manufacture of his lens, while Mr. Franklin-Adams gave to Cooke & Sons an order for three lenses—4-inch, 6-inch, and 10-inch.

In 1902 an English equatorial mount was designed and made by Messrs. Cooke. A full report of this was communicated to the Society and published in *Monthly Notices*, vol. lxiv. p. 608, together with an account of a year's work with the complete instrument at the Cape in charting the Southern Hemisphere ; this was completed at the Cape Observatory by the kind permission of Sir David Gill, who also gave much valuable assistance, including an electric installation and the taking of a series of plates in the astrographic telescope, corresponding to the centres of a defined number of plates in each zone of the Franklin-Adams chart. The photographic plates as finished were sent home in batches, and always in a steamer that did not carry their fellow transparencies, their numbers being as follows :

In.	In.		Plates
15	15	chart plates—2^h exposure	127
12	10	„ „	127
15	15	„ three exposures of 7^m each... ...	127
Transparencies			381
		Total	762

The complete instrument and its house, weighing in all about twelve tons, were brought to England and erected at Mervel Hill, Hambledon, Surrey, in 1904, and were adjusted, and working well by the end of the year.

Report for 1905.

First—to carry on the report of the charting cameras during 1905—the transition from the brilliance of the South African skies to that of England was sad indeed. On very fine nights two hours twenty minutes is the exposure required to compare at all with the Cape work, but saddest of all is the frequent loss of time and cost of two plates, for with such large plates and the varying refraction, uncompleted plates cannot be carried on to the next fine night, but have to be sacrificed.

Subject to revision and final examination the following plates have been secured during 1905 :

In.	In.		Plates.
15	15	chart plates—usual exposure $2^h\ 20^m$	46
12	10	„ „ „	46
15	15	„ triple exposure each of 7^m	38
		Total	130

As these have not to take the risk of crossing the sea it is not proposed to make transparencies.

Other instruments now mounted are :—Twin steel telescope carrying a 6-inch triple achromatic object-glass by Cooke, and an 8-inch by Wray (refigured by Mr. Dennis Taylor), both of 108-inch focus.

A 10° object-glass prism is mounted in such a way as to be available for either of the object-glasses. A new clock by Repsold has been bought and will replace the present controlled clock as soon as possible.

For time determination a meridian circle by Jones with object-glass of $3\frac{1}{2}$-inch aperture and 57-inch focal length is used. Messrs. Cooke have added a new circle.

The Frodsham clock has been overhauled, cleaned, and furnished with a nickel-steel pendulum ; it is mounted upon an isolated brick wall with two-thirds lime and one-third cement, and fastened with three 1-inch steel bolts. In a month after being mounted the clock gave very satisfactory results.

In the transit-room is a prime vertical by Troughton & Simms, object-glass aperture $3\frac{1}{2}$ inches, focal length 42 inches.

All the buildings are lighted by a current of 120 volts and all the instruments by one of 15 volts. The English equatorial has electric motors in declination and R.A., the twin telescope in R.A. only ; all instruments are in electrical communication with

the chronograph. It is driven by a slave clock in the transit-room, which itself is controlled by the Frodsham clock in the library.

The daily routine work consists of meteorological observations, including sunshine recorder and (weather permitting) time determinations, always accompanied by collimator, azimuth mark, and nadir observations.

Special work begun during the year consists of a series of Sun-spot pictures, taken with the twin telescope, upon very slow wet collodion plates, the slowness of which, together with the five-diameters magnification by a Barlow lens, gives an exposure which, compared to a rapid dry plate, is under one two-millionth of a second.

The other principal work done during the year was the organising of an eclipse expedition to Tunis, which came about in the following way :—

After the eclipse of 1900, when this Observatory took part with Dr. Copeland in the Scottish expedition to Santa Pola, Mr. Crookston, of Glasgow, who had a mining establishment in Algeria, bordering on Tunis, in the district of Boulhaf-le-Dyr, was asked to allow his manager to take meteorological observations for the summer and early autumn months ; these were very satisfactory. When 1905 arrived Mr. Crookston offered to house the expedition. This offer would have been gratefully and at once accepted had it not been that Gijon, in the north of Spain, well known to Mr. Franklin-Adams in the eclipse of 1860, was unoccupied, because of its bad meteorological record, and it was nearly settled to go there. At this point Professor Becker, of Glasgow, who was proposing to go to Burgos, was asked whether the two Observatories could proceed together to Gijon, but after writing to the British Consul, and hearing about the class of steamers, it was finally decided to go to Tunisia, to a site about 3000 feet above sea-level.

The object of the expedition was (1) to secure automatic and exactly measured exposures of a long series of photographs for the determination of coronal intensity at various distances from the Sun's limb. This was carried out by Professor Becker with a most ingenious apparatus mounted and mostly constructed by himself. (2) To obtain photographs on slow wet collodion plates with the three short-focus Franklin-Adams lenses, 4 inches, 6 inches, and 10 inches, which would assist in investigation (1). On consideration, however, the last two were omitted, in order to avoid the stoppage of the charting work at home, and instead the 6-inch photo visual, focus 108 inches, was taken, together with a new mount by Cooke, specially made for an 18-inch mirror (borrowed from Edinburgh), and a new Repsold clock also specially bought, in order not to dismantle the English equatorial, and thus allow charting to go continuously forward. The result of the expedition when worked out will be published in due course.

All was entirely successful, excepting only the long-exposure photographs with the short-focus lens, which, on account of the strong light during the eclipse, were absolute failures, and would have been over-exposed in three seconds instead of the three minutes which were given.

A preliminary account of Professor Becker's work and instruments has been published by the Joint Eclipse Committee.

Mervel Hill is about 120 feet above the plain and 420 feet above sea-level; it slopes on the north side gently towards the Hog's Back, but has an abrupt descent to the south and west. From the house there is a splendid horizon, only interrupted as to a few degrees in two places; there is a prospect of over a thousand square miles. The site was chosen in preference to Crowborough or Hind Head on account of the much smaller number of nights obscured by the hill mists so prevalent upon sandy hills in the South of England.

The longitude has not yet been electrically determined; the six-inch Ordnance Map gives $2^m\ 30^s{\cdot}2$ W., $51^\circ\ 8'\ 11''$ N.

Sir William Huggins's Observatory, Upper Tulse Hill.

The photography of the spectra of stars and of other celestial bodies, which has been in progress for many years, is being continued.

Experimental work in the laboratory has included, in addition to the photography of spectra, further experiments in the radiation of radium, of which the results have appeared in the *Proceedings of the Royal Society.*

Rousdon Observatory, Lyme Regis, Devon.
(Sir W. Peek's; C. Grover, Observer in charge.)

The building and instruments have been maintained in their usual order, and observations were made on 132 nights. April was the most unfavourable month of the year; August to November were four remarkably fine observing months. The 6·4-inch Merz equatorial has been kept at the observations of long-period variable stars; 412 magnitude determinations have been made by Argelander's method. At each observation the light of the variable is estimated relatively to five comparison stars in the same field of view, the mean result being assumed to be the magnitude on the date of observation. During the twenty years this work has been in progress 9·300 magnitudes have been

recorded, and 361 maxima and 280 minima have been observed. About 25 long-period variables are under regular observation.

The lunar eclipse on February 19 and the solar eclipse on August 30 were well observed here.

Mr. Saunder's Observatory, Crowthorne, Berks.

Measures have been commenced on a photograph of the Moon taken by Mr. Ritchey with the Yerkes 40-inch refractor. Over 1800 points have been measured twice in one position of the plate. Three hundred of these have also been measured twice in the reversed position, and constants have been found for the plate. It has been found that it is now possible to use the method suggested by Professor Turner (*Monthly Notices*, vol. lx. pp. 202–205). This affords some indication of the progress made, as two previous attempts to use this method have failed in consequence of its not being possible to obtain a sufficient number of standard points whose positions were well known and widely distributed. The measures have been made, as before, by Mr. Hardcastle.

The telescope continues to be used chiefly for the study of fine detail on the Moon, and a map has been prepared for publication in the *Memoirs* of the B.A.A. showing the present state of our knowledge of the *Ptolemæus* region.

The telescope has also been occasionally employed for comet seeking.

Daramona Observatory, Streete, Westmeath. (*Dr. W. E. Wilson.*)

Practically no observing or photographic work was done during the past year. The long period of wet and cloudy weather from which we have suffered for some years seems to show little signs of passing away. During the past year rain was recorded on 246 days, although the amount measured was only 28″·36, against 36″·27 in 1904 and 45″·72 in 1903, when there were 265 wet days.

A quartz spectroscope was mounted for photographing the ultra-violet spectrum of sun-spots, but no work was done with it, as the Sun was seldom free from clouds. Experiments were made with a new apparatus for recording the amount of solar radiation.

Kodaikánal and Madras Observatories.
(C. Michie Smith, Director.)

The year was, on the whole, favourable for solar observations, and there were only twenty days on which no work was possible.

Photoheliograms were taken on 327 days, and the number and approximate positions of the spots and faculæ were determined by projection or by eye observations on 345 days. In all 294 new groups of spots were recorded during the year. There were two days on which no spot was visible (July 28, 29), and the mean daily number of groups was 4·7.

Spectroscopic Work.—Observations of spot spectra were made on 179 days, and prominences were recorded on 297 days. The spectroscopic observations have been made more completely than in former years, and a large number of interesting observations have been obtained. As practically all the work has to be done in the early forenoon hours and with a single instrument, the observations are still less complete than they ought to be, but as soon as additional assistance is available the eye observations will be supplemented by photographic work.

Spectroheliograph.—Photographs with the spectroheliograph were taken on 317 days. Over 1000 photographs were taken, but of these a considerable number had to be rejected for one reason or another. The instrument continued to give satisfaction except as regards the slits, which were a constant source of trouble. Steps are being taken to replace the collimating slit with one more suitable for the work that has to be done. Next to the slits the chief cause of trouble was the unsteadiness of the air. This, at times, is very serious. It is due largely to the unsuitable position chosen (during the director's absence) for the instrument. Various attempts are being made to get rid of this trouble, but the success, so far, is only partial. Many good spectroheliograms have, however, been obtained both of flocculi and prominences. The prominence plates are compared day by day with the records made with the spectroscope, and the published lists will in future contain all prominences observed both visually and photographically.

Publications.—Three *Bulletins* have been published containing observations of spot spectra and prominences, and a fourth dealing with spot spectra to the end of June 1905 is in type.

At the Madras Observatory astronomical work has, as for some years past, been confined to the observations necessary for the time service. The chief matter of interest during the year was the substitution of Indian standard time for Madras time from July 1. The new time is exactly $5^h\ 30^m$ fast of Greenwich mean time, and has been accepted over a great part of India. It is used over the whole of India for railway, postal, and telegraph purposes.

Melbourne Observatory. (*Director, Mr. P. Baracchi.*)

Meridian Work.—The following observations were made with the 8-inch transit circle :—

	Observations in R.A.	Observations in N.P.D.
Clock stars	541	—
Azimuth stars	299	104
List stars	1169	1173
Miscellaneous	3	3
Total	2012	1280

The list stars were, as in previous years, selected from the Melbourne Plates of the Astrophotographic Catalogue to be used as reference stars for the reductions of these plates. The total number of reference stars which have now been observed no less than three times in both R.A. and N.P.D. is 5211. These have been reduced as far as was required for the construction of the usual annual catalogues up to the year 1904 inclusive, and the places of about one-half of them have been brought up from the annual catalogues to the epoch 1900 as a commencement in the preparation of a general catalogue for that epoch, which will contain all the stars observed during the period 1894–1906, including the full list of reference stars required for the Melbourne plates at the rate of ten stars per plate.

Astrophotographic Work.—

	No. of Plates.		
	Passed as Satisfactory.	Rejected.	Total Number passed as Satisfactory up to 1905 Dec. 31.
Chart plates with triple exposures of 30^m each	74	3	556
Catalogue plates (second series) ...	25	2	316
Test plates on South Polar regions	20	—	—
Test plates on Oxford type charts	10	—	—
Plates for trails, adjustment of focus, centres, &c.	3	—	—

The measurement of Catalogue plates has been carried on, as in former years, by a special bureau. (See joint report for Sydney and Melbourne, p. 213.)

All the instruments which record photographically the variations of the magnetic elements, meteorological elements, and seismic disturbances have been at work throughout the year without interruption.

Further progress has been made in the measurement and reduction of the daily magnetic curves of all past years since 1868. It is expected that the register of hourly ordinates for the whole period up to 1905 December 31 will be completed this

year, after which the cataloguing and classification of disturbances for the same period will be taken in hand systematically.

The usual routine operations in connection with the following services have been carried on to meet local public requirements, as in previous years, viz. :—

The local and inter-State weather service,
The time service,
Registration of tides at four localities,
Rating of chronometers,
Testing instruments (surveying, meteorological, &c.),
The official verification and issue of standard weights and measures, &c. &c.

Sydney Observatory. (*Acting Director, Mr. H. A. Lenehan.*)

The transit circle has been in constant use, the chief work being observations of guiding stars for the astrographic plates.

Number of observations of	R.A. of stars ...	2395
„ „	N.P.D. of stars ...	2032

The Sun was observed on all available occasions. The cloudy weather, while lessening the number of meridian observations, gave an opportunity of bringing up the previous years' reduction to a more advanced stage. The 1904 constants have been computed and checked, stars identified, and precessions nearly finished. Progress has also been made with the 1905 reductions. The 11¼-inch equatorial was used for the eclipse of the Sun and for occultations, and visitors also were allowed to view the more interesting objects. There were 1405 visitors during the year, of whom 829 attended in the evening. Lectures with the equatorial or lantern slides occupied 78 nights.

The astrographic work at the Red Hill Branch was as follows : 193 plates were exposed, many being triple exposures of twenty minutes each. The stock of plates was examined and classified, and those showing any deterioration were noted to be re-taken. In conjunction with Mr. Baracchi, the Government Astronomer for Victoria, the reproduction of the charts has been discussed. The adoption of the French method of process prints, or the Greenwich method of reproduction on photographic paper, will depend upon the funds eventually placed at our disposal.

On February 20 a successful set of photographs of the lunar eclipse were taken, and Mr. Short also succeeded in obtaining a good series of photographs of the solar eclipse of March 6.

In the early part of January signals were received from the Washington Observatory *vid* Vancouver, Fanning Island, Samoa, Norfolk Island, and Southport. Notwithstanding the five repeating stations the loss was only 2·96 seconds.

The Government Astronomer, Mr. H. C. Russell, retired on February 28. In view of the probability that the Observatory will be taken over by the Commonwealth Government no steps have been taken to appoint a new Director.

Joint Report of the Government Astronomers of New South Wales and Victoria on the Measurement of the Sydney and Melbourne Plates of the Astrophotographic Catalogue.

This work has been continued throughout the year by a special bureau established at the Melbourne Observatory and maintained at the joint expense of the Governments of New South Wales and Victoria, as stated on previous occasions.

The measurements were made with two micrometric machines constructed for the purpose by the Repsolds on the plan of Sir David Gill (as described in *Monthly Notices*, vol. lix. pp. 61–72), following the same methods and rules adopted in previous years.

Three new assistants were appointed during the year to fill vacancies caused by resignation or sickness.

The bureau is in full strength at present and the equipment is in good working order.

The measurements made during the year are as follows :—

99 Sydney plates, containing 74,797 stars.
79 Melbourne plates, containing 36,378 stars.

The whole work up to 1905 December 31 stands thus :

413 Sydney plates, containing 250,816 stars.
655 Melbourne plates, containing 223,645 stars.

Perth Observatory, Western Australia.
(*Director, Mr. W. E. Cooke.*)

Astrograph.—Progress is being made with the catalogue plates for the Astrographic Catalogue. Unfortunately a consignment of plates was lost by the wreck of the *Orizaba*, and work was delayed from February 11 till June 22.

During the year only 214 plates were passed as satisfactory, bringing the total up to 1088. It is difficult to know how to deal with these plates. It is impossible to measure them with the present staff whilst continuing the current programme, and it may be found necessary, as soon as the catalogue series is completed, to discontinue astronomical observations for some years, in order that the plates may be measured.

Transit Circle.—A change in the scheme of observations was made during the year, owing to the formulation of a new policy for the future. A notice of the new scheme has been already communicated to the Royal Astronomical Society, and the

following will probably be sufficient for the present sketch. The observing list comprises two or three stars in every square degree between the declination of 31° and 41° S. These stars were selected in the first place as standards for the astrographic plates, but it is now proposed to continue observing the same list over and over again, making, if possible, three determinations of position of each star per decade. At first the R.A. was made to depend upon the positions of equatorial stars in the *Nautical Almanac*, and the zenith distances upon nadir reflections. An entirely different method is now proposed. A list of 406 secondary standards has been prepared, each of which will be observed about ten times, and their positions in both co-ordinates will depend upon those of the stars in Dr. Auwers's Fundamental Catalogue situated between 31° and 41° S. These secondary standards will then be used to fix the positions of the stars in the main catalogue, which will be observed in zones of 2°.

The observation of the secondary standards was commenced on August 9, and 1842 observations have been made in both R.A. and Dec., and the reductions are well forward.

In the early part of the year, 1768 observations in both co-ordinates were made of the stars in the general list (zone 33°–34°). These were fully reduced and entered in ledgers. Zone 39°–40° was also entered in the ledgers, and a portion of zone 31°–32°. The following is the result of the year's work in tabular form :—

Nights on which time was determined		182
Observations of zone stars (33°–34°) in R.A....		1768
„ „ „ „ in N.P.D.		1768
Observations of secondary standards in R.A....		1842
„ „ „ in N.P.D.		1842
Observations of clock stars in R.A.		954
Separate determinations of	Collimation error...	13
	Level „ ...	235
	Azimuth „ ...	231
	Nadir point ...	58
	Flexure	4
Reading of meridian mark		112

Meteorological.—The usual meteorological work has been continued. A new system of issuing forecasts was started at the beginning of 1905, and has proved very successful.

Miscellaneous.—The time service has been efficiently maintained, but the time ball at Fremantle was dismounted at the beginning of May, owing to the erection of the fort, and remounted again on October 8.

Dr. Hessen arrived in Perth about the middle of October in

charge of the International Geodetic Observations for variation of latitude, and was able to mount his zenith telescope at the Observatory and make some preliminary observations. He has now established his Observatory at Bayswater, a suburb of Perth.

Dr. Alessio, navigating officer of the Italian cruiser *Calabria*, arrived at Fremantle in December, and made a determination of the force of gravity, and also the magnetic values at the Observatory. These will be eventually reduced and published by him.

Lovedale Observatory, South Africa. (*Dr. Alex. W. Roberts.*)

The work at Lovedale during 1905 has been on the same lines as in former years.

One hundred and five variable stars are under regular observation, and 4100 separate observations have been secured.

Especial attention has been directed to stars whose variation is apparently due to eclipse in some form. An attempt has been made to determine the orbital elements of the most remarkable of these stars, while towards the close of the year a scheme of observations was planned which might aid in the direction of arriving at some knowledge of the absolute dimensions of eclipse variable stars.

Mr. Tebbutt's Observatory, the Peninsula, Windsor, N.S. Wales.

The only astronomical observations made during the year 1905 are filar-micrometer comparisons during six nights of *Uranus* with the well-determined star I *Sagittarii*, and numerous measures of the interesting binary stars α and γ *Centauri*, Burnham 416, γ *Coronæ Australis*, and β *Muscæ*. All these observations have been made with the 8-inch equatorial, and will be communicated as soon as possible to the Society. The usual meteorological observations have also been made during the year.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1905.

Fifty-eight new planets were discovered, or first announced, in 1905 as follows :—

Letter and Number.	Date of Discovery.	Discoverer.
PQ ...	1905 Jan. 1	Wolf
PR ...	,, ,, 1	,,
PS 554	,, ,, 8	Götz
PT 555	,, ,, 14	Wolf
PW 556	,, ,, 8	Gotz
PY 557	,, ,, 14	Wolf
PZ ...	,, Feb. 9	,,
QA ...	,, ,, 9	,,
QB 558	,, ,, 9	,,
QD 559	,, Mar. 8	,,
QE ...	,, ,, 13	Götz
QF 560	,, ,, 13	Wolf
QG 561	,, ,, 26	,,
QH 562	,, Apr. 3	,,
QK 563	,, ,, 6	Götz
QL ...	,, May 7	Wolf
QM 564	,, ,, 9	Götz
QN 565	,, ,, 9	Wolf
QO 566	,, ,, 28	Götz
QP 567	,, ,, 28	,,
QQ ...	,, June 28	Wolf
QS 568	,, July 27	Götz
QT 569	,, Aug. 1	Palisa
QW ...	1904 Apr. 4	Frost
QX ...	1905 July 30	Wolf
QZ ...	,, Sept. 4	Götz
RB ...	,, ,, 19	,,
RC ...	,, ,, 19	Wolf
RD ...	,, ,, 19	,,
RE ...	,, ,, 19	,,
RF ...	,, , 22	,,
RG ...	1903 Sept. 22	Dugan
RH ...	1905 Oct. 20	Wolf
RJ ...	,, ,, 20	Kopff
RL ...	,, ,, 24	Wolf
RM ...	,, ,, 25	,,
RN ...	,, ,, 24	,,
RO ...	,, ,, 25	,,
RP ...	,, ,, 25	,,
RQ ...	,, ,, 26	Kopff
RR ...	,, Nov. 3	Wolf
RS ...	,, Oct. 26	,,
RT ...	,, ,, 26	,,
RU ...	,, ,, 26	,,
RV ...	,, ,, 26	,,
RW ...	,, ,, 26	,,
RX ...	,, Nov. 1	,,
RY ...	,, ,, 1	,,

Letter and Number.	Date of Discovery.	Discoverer.	Letter and Number.	Date of Discovery.	Discoverer.
RZ ...	1905 Nov. 1	Wolf	SE ...	1905 Dec. 17	Wolf
SA ...	„ „ 3	„	SF ...	„ „ 5	Metcalf
SB ...	„ „ 3	„	SG ...	„ „ 27	Wolf
SC ...	„ „ 3	„	SH ...	„ „ 24	Metcalf
SD ...	„ „ 3	Kopff	SP ...	„ „ 31	Palisa

569, SP, were discovered at Vienna, QW at Arequipa, SF, SH at Taunton, Mass. ; the remainder at Heidelberg.

The following planets do not receive permanent numbers, not having been sufficiently observed : PQ, PR, PZ, QA, QE, QL, QQ, QW.

The following identities have been established : PV with 149 *Medusa*, PX with 517, QC with 427, QE with 311 *Claudia*, QR with 216 *Cleopatra*, QU with 406, QV with 263 *Dresda*, QY with 167 *Urda*, RA with 429, RK with 509 *Jolanda*, 522 with KN, 550 with FT and also with LX, 566 with JF, 568 with an unnamed planet discovered 1891 December 1. The following identities are more or less probable : PU with 489 *Comacina*, QJ with 480, RN with 477 *Italia*, 526 with HA. Planet RJ is considered doubtful. A planet photographed on 1902 February 24, and at first supposed to be 462 *Eryphile*, proved to be 537 : this object was again photographed six days later.

522, 554 have been detected on plates taken 1901 August 23, 1900 September 30 respectively. In the latter case the planet was in the *Pleiades*, and being stationary it did not trail on the plate and so escaped detection at first.

The interesting planet 475 *Oello*, which has a very eccentric orbit, was re-observed last year, thus enabling its elements to be accurately determined.

The following planets have received names : 406 *Erna*, 485 *Genna*, 486 *Cremona*, 489 *Comacina*, 494 *Virtus*, 504 *Cora*, 505 *Cava*, 511 *Davida*, 520 *Francisca*, 522 *Helga*, 542 *Susanna*, 544 *Jetta*, 554 *Peraga*, 565 *Marbachia*, 566 *Stereoscopia*, 568 *Cheruskia*, 569 *Misa*.

Dr. Gustav Witt, the discoverer of 433 *Eros*, has reinvestigated the orbit of that planet from the observations of 1893, 1894, 1896, 1898, 1899, 1900, 1901, 1903. Those of the first three years are from Harvard photographs ; in 1903 only two observations are to hand, both made by Professor Millosevich in Rome. Perturbations by *Venus*, Earth, *Mars*, *Jupiter*, *Saturn* were computed at twenty-day intervals by Herr Wedemeyer. Sixteen normal places were found covering the ten years of observation, two different values being given to the 1896 normal according as some discordant observations were kept or rejected. In solving the normal equations an attempt was made to deduce a correction to the assumed mass of the Earth, and consequently to deduce a solar parallax. The values of the parallax deduced

are 8″·794 or 8″·803 according as one or other of the 1896 normals are employed; the observations of 1893, 1894, 1896 are evidently much less accurate than the later ones, as is only to be expected from the fact that the planet was still unknown and no special precautions could be taken to secure accuracy. There is every reason to hope that this gravitational method will in time give a very precise result for the solar parallax. The final elements are:

Epoch and osculation 1898 August 2·0, Berlin M.T.

	°	′	″	
M_0	205	4	51·8	
ϕ	12	52	24·2	
ω	177	39	11·2	1900·0
Ω	303	31	48·2	1900·0
i	10	49	35·0	1900·0
μ	2015″·27547			

A. C. D. C.

New Satellites.

Two additional satellites of *Jupiter* have been discovered at the Lick Observatory by Mr. Perrine from photographs taken with the Crossley reflector. VI. was discovered in 1904 December, and VII. a month later; their magnitudes are 14 and 16, implying diameters of about 100 miles and 30 miles respectively. Their direction of orbital motion was uncertain for some time, but it has now been ascertained to be *direct* in each case; they therefore fail to support Professor W. H. Pickering's theory, described in last year's Report, according to which the motion of all very distant satellites should be *retrograde*. The interesting features are the high inclinations of the orbits to the primary's equator and orbit (in each case about 30°, though the two satellites move in quite different planes) and the near approach to equality in the sizes of the orbits. However, as the eccentricity of each is large and the major axes in different directions, the two orbits (which interlock like links in a chain) are about 1½ million miles apart at their nearest point.

Dr. F. E. Ross has computed the following orbits for these two satellites:—

Satellite. Epoch.	VI. 1905 Jan. 0·0 G.M.T.	VII. Same.
Mean Jovicentric R.A.	289°·1	328°·2
Longitude of Perijove	270	337
R.A. of N. Pole of orbit	86·7	191
Declination	84·5	64
Semi-axis major at dist. 5·2 ...	50′·6	52′·5
Period	251 days	265 days
Eccentricity	0·156	0·025
Motion	Direct	Direct

The elements of VI. were corrected by the observations of the satellite made in July, but those of VII. were only based on the two months following discovery, and while the position of the orbit plane is probably nearly correct, subsequent observations show that the period and eccentricity are erroneous ; the former seems to be about 254 days, the latter about 0·20, the longitude of perijove about 132°.

Dr. Ross has also investigated the orbit of *Saturn's* ninth satellite *Phœbe*, which was again under observation in 1905. He has investigated and applied the solar perturbations, including the motion of the node and perisaturnium. The period and eccentricity are modified by these corrections, and become $550^d{\cdot}44$, 0·166. The annual tropical motions of π, Ω, i are $-0°{\cdot}268$, $+0°{\cdot}435$, $-0°{\cdot}020$ (*Annals of Harvard College Observatory*, vol. liii. No. vi.).

Professor W. H. Pickering has announced the photographic discovery of a tenth satellite of *Saturn* with a period of 21 days, interesting from its large eccentricity and inclination and from the near approach which it appears to make to *Titan*. The orbit, however, cannot be considered as definitely known till further observations are available. A. C. D. C.

The Comets of 1905.

Few comets have been discovered during the year, but the following notes may be added concerning some mentioned in the last Annual Report.

Comet 1904 a = 1904 I. (parabolic) was followed at Strassburg till May 9, when the distance from the Earth was more than 5 R. The physical appearance and photometric changes of this comet have been discussed in great detail by Dr. C. W. Wirtz, of Strassburg, in *Ast. Nach.*, No. 4002.

Comet 1904 d = 1904 II. was observed at Nice till May 2. Parabolic elements by Professor Aitken represent the path of the comet very accurately.

Comet 1904 e = 1905 II. was last observed on May 24 at Washington. It is probable that the period of this comet will prove to be about seven years. Definitive elements have not yet appeared, and those of Dr. Wedemeyer founded on about four weeks' observations leave large residuals in the observed Right Ascension. It has been suggested that this comet may be identified with one that appeared in 1783, and for which the late Dr. C. H. F. Peters computed an ellipse of 5·89 years period.

Concerning the comets of the current year, 1905, on March 26 M. Giacobini discovered a telescopic comet as it was approaching perihelion. The comet became too faint for observation about the end of May, and the two months' observations are best represented by an ellipse of about 200 years period.

On November 17 M. Schaer, of Geneva, described a comet

which a few days later became visible to the naked eye. When first seen the comet was near the North Pole, but a rapidly southerly motion, coupled with loss of lustre, has prevented a long series of observations. There is no reason to suspect deviation from a parabolic path.

M. Giacobini added another to his list of cometary discoveries by detecting on December 6 a faint telescopic comet, the orbit of which is marked by small perihelion distance. As a consequence the comet can become very bright as it approaches the Sun. Observations are now discontinued, but the comet may become visible in daylight. After perihelion the comet should be seen in the Southern Hemisphere, and may be again visible in these latitudes later.

In addition to this list it is to be inferred from a telegraphic communication from the Lowell Observatory that Mr. Slipher obtained evidence of the existence of two comets on a plate exposed on November 29, one of which showed a double tail. As the announcement was not made for some time after the plate was taken, and the motion of the comets was uncertain, no further observations have been possible. The part of the sky photographed was in the constellation Aquarius.

Tempel's first comet (1867 II.), especially interesting on account of the unusual perturbation of its orbit, and for which a sweeping ephemeris was prepared by M. Gautier, passed through perihelion about April without being seen, though the conditions were favourable. Barnard's Comet of 1892 may also have passed its perihelion passage, but its position is very doubtful.

Definitive orbits of the following comets have been published during the year :—

Comet.	Character of Orbit.	Calculator.	Authority.
1886 VIII.	Parabolic	Fagerholm	*Ast. Nach.* No. 4047
1844 II.	Elliptic	Ross	*Ast. Nach. Ergänzungsheft*, No. 9
1903 III.	Parabolic	Peck	*Ast. Jour.* No. 573
1886 I.	Hyperbolic	Svedstrup	*Monograph*

The discussion of the orbit of the last-named comet by the late Dr. Svedstrup is particularly interesting. The comet was visible for several months, and forty-four normal places were formed, but these were not satisfactorily represented by the derived elements. Several hypotheses were tried with the view of effecting a better agreement, but the most satisfactory was to introduce into the equations of condition an additional term depending upon the mass of the comet. On solution a negative value for the mass was obtained, or the correction to the assumed mass of the Sun and comet combined was negative. This example, so far as it goes, shows that it is desirable to look for evidence of the action of radiation pressures in cometary obser-

vations. It also offers an independent proof of the generally received opinion that a comet is formed by the aggregation of a number of discrete particles. W. E. P.

Progress of Meteoric Astronomy in 1905.

January Meteors.—On January 2, during watches amounting in the aggregate to $2^h\ 11^m$ between $15^h\ 14^m$ and $18^h\ 44^m$, Mr. T. W. Backhouse, of Sunderland, saw 68 meteors, of which 62 belonged to the special shower of the epoch.

During the last five years fireballs have been very numerous in January, and the periods January 10–13, 24–25, and 27–29 appear to have been specially productive. The principal radiants have been in the region of *Monoceros* and *Hydra*.

April Meteors.—Moonlight and cloudy weather prevented observation.

August Meteors.—The shower was only a moderate one, and not very successfully observed. There occurred a fair number of fine nights during the first half of August, but at the time of the maximum display a gibbous Moon overpowered the fainter meteors.

October, November, and December Meteors.—None of these displays was well observed. Very few *Leonids* were expected, six years having elapsed since the probable (though unobserved) return of the parent comet in 1899, and the Moon was at the full. At Bristol on the morning of November 16 a few of the usual streak-leaving *Leonids* were seen from the normal radiant. On November 15 Mr. J. R. Henry, of Dublin, watched between $10^h\ 45^h$ and $14^h\ 35^m$ and counted 22 meteors, including 18 *Leonids*. The shower therefore returned in a distinct form, though its manifestation was by no means conspicuous.

The *Andromedids* of Biela's Comet were carefully looked for on November 18 and nights near that date, as there seemed a prospect of an abundant return. But the Earth encountered very few, if any, of these meteors. Reports from many widely distant places of observation agree that the shower was practically invisible. Mr. E. F. Sawyer, of Brighton, U.S.A., says that observations were obtained on every evening between November 14 and 30 (except November 15 and 28), and that meteors generally were scarce ; those radiating from γ *Andromedæ* were remarkably so, only two small ones being recorded (on November 24) intersecting at $26° + 42\frac{1}{2}°$.

The absence of meteors from this rich system is noteworthy when we remember that it furnished showers in 1902, 1903, and (more conspicuously) 1904. Many of the meteors of the stream appear to have a shorter period and to be more widely distributed along the orbit than formerly. The dense group closely accompanying the comet seems to have experienced disturbance by *Jupiter* and *Saturn*, enabling it to pass more than a

million miles outside the Earth's orbit according to the computations of Dr. P. V. Neugebaur (*Proc. Royal Society*, A, vol. lxxvi. p. 270).

Though the *Andromedids* failed there were a few brilliant meteors from *Taurus* between November 19 and 24. These were seen by the writer at Bristol, Mr. C. L. Brook at Meltham, near Huddersfield, Rev. W. F. A. Ellison at Enniscorthy, and Mr. G. Smith at Bristol. The radiant of 9 well-observed paths was at 58°+9°. These slow long-pathed *Taurids* often present a well-marked display at the period of the *Leonids*.

The fireballs of the year were neither numerous nor well-observed. In January and February, however, large meteors were frequent (*Observatory*, vol. xxviii. p. 212), though succeeding months supplied few examples. At the close of the year (December 30) a magnificent object was seen in the early evening twilight (at $4^h\ 26^m$) by many observers in Scotland and the northern counties of England. It left a bright train, which assumed a zigzag shape and continued visible for a quarter of an hour. The observations are not very precise, but they indicate that the radiant was in the S.E. region of *Cetus*, and that the fireball descended from a height of about 60 to 47 miles during its long and slowly traversed path.

The following is a list of the real paths of a few bright meteors observed in England during the past year :—

Date.	G.M.T.	Brightness.	Height at First. Miles.	Height at End. Miles.	Length of Path. Miles.	Velocity per Sec.	Radiant Point.	Observers.
1905.	h m						° °	
Jan. 14	10 16	> ♀	60	29	55	15	119+ 3	3
27	11 58	½ ☽	66	33	53	7	118± 0	5
29	6 20	4 × ♀	57	25	67	23	130+33	5
Feb. 11	10 22	> ♀	51	32	46	13	150− 7	4
11	10 31¾	= ♀	62	20	54	20	166+33	6
11	11 45	3 × ♀	63	46	40	12	145−13	13
28	12 10	> ☽	69	28	94	...	150−11	10
Mar. 18	8 47	½ ☽	47	43	60	...	168−23	2
May 10	12 45	> 1	69	39	43	32	137+76	2
19	9 50	♃	56	49	...	...	254−20	3
Aug. 9	10 17½	1½ ♀ ♆	69	52	32	...	44+59	2

Professor D. Eginitis gives a list of meteoric radiants recorded at the National Observatory at Athens in 1903 and 1904 in *Ast. Nach.* No. 4032. Dr. A. A. Nijland, of Utrecht, also summarises his observations of *Lyrids*, *Perseids*, and *Leonids* in the same number. Particulars of the *Andromedid* shower in 1904 November 21, as seen by Bohlin at Stockholm, are to be found in *Ast. Nach.* 3997.

Aerolite of 1902 *November* 15.—A recent number of the *Scientific American* gives details of the stony meteorite which fell with a great noise in Bath County, fifty miles east of Lexington, on the above date after a long luminous flight through the heavens above Ohio and Kentucky. Before striking the ground the mass divided into several fragments, three of which were found—viz. one of 184 lb., another of 10 lb. 10½ oz., and a third of ½ lb. "The large stone is furrowed and highly oriented. The trend of the furrows shows a regularity indicating the constancy in the position of its axis after the mass entered the air and in pursuing its lengthy flight. Its composition presents a base of fine compact olivine and enstatite with abundant sparkling points of nickel. It also has numerous white and grey spherical chondri of similar material distributed through it. Its surface exhibits a primary and secondary crust."

Aerolite of 1904 *August* 13.—Fell at 8 P.M. at Shelburne Grey County, Ontario, Canada. The noise accompanying its descent was heard over a radius of 35 miles. Two pieces were found distant from each other half a mile, the larger being 27¾ lb. and the smaller 13 lb. in weight. The stones fell vertically and could not have been hot, for the larger one, which buried itself 2 feet beneath the surface in a field of oats, carried with it a large burdock leaf which was green and uncharred. The velocity of the large stone was calculated at about 550 feet per second. That of the *Hvittis* meteorite was 590 feet per second. The meteorite which fell on 1881 March 14 at Middlesbrough, Yorks, appears to have exhibited a slower speed than either of these, for Professor Herschel calculated that its velocity on striking the ground was only 412 feet per second. It seems evident that when bodies of this character drop to the Earth, atmospheric resistance and terrestrial attraction have robbed them of their original speed and direction, and that their motion is extraordinarily slow in comparison with the planetary velocity exhibited by ordinary shooting stars at normal heights in the air.

W. F. D.

Total Solar Eclipses.

1905 *August* 30.

As pointed out in last year's Report this eclipse derived considerable importance firstly from the fact that it was the last one visible from any accessible place for many years, and secondly from the long interval of time that elapsed between totality in Labrador and in Egypt. Extensive arrangements were accordingly made for its observation.

A large number of French observers were distributed along the line in Spain, Algeria, and Tunisia, among whom we may note :—

MM. Janssen, Millochau, and Stefanik at Alcosebre ; M.

Deslandres at Burgos ; MM. Trépied, Salet, Bourget, Montangerand, and many others at Guelma or its vicinity ; M. Bigourdan at Sfax.

The preliminary reports of most of these parties have been published in *Comptes Rendus* (1905, No. 12 *et seq.*), from which we may extract the following points of interest :—

M. Trépied obtained photographs of the corona and chromosphere confirming the close connection between the forms of the coronal streamers and regions of solar disturbance, and one showing the whole of the Moon's disc outside totality. His photographs also show the elliptical rings in the corona which are such a marked feature of the large-scale plates taken by the Astronomer Royal at the same station.

M. Deslandres was unfortunate in his weather, as the Sun was covered with clouds at both second and third contacts. A partial clearance, extending over about one minute during the total phase, enabled some measurements of the brightness and total luminosity to be made, the reductions of which have not yet been published.

M. Salet at Robertville, in Algeria, made some polarimeter observations with a "Savart," and found bands showing radial polarisation up to a distance of $1\frac{1}{2}$ solar diameter from the limb. The maximum polarisation was found at 5′ or 6′ from the limb, and it was noted that the presence of prominences had no apparent effect upon the bands, thus putting "out of doubt the non-polarisation of protuberances."

MM. Bourget and Montangerand at Guelma obtained good spectrum observations, though their spectra of the corona show only the "green" line. A discussion of their prismatic camera photographs leads them to the conclusion that there is marked division of the chromosphere into two regions or shells—viz. the lower or "reversing" layer, extending only 1″ from the limb, and the upper or "chromospheric" layer, extending to 3″ or 4″.

Measurements of the intensity of the continuous coronal spectrum showed that, as compared with that of diffused sunlight, it was more intense in the region from λ 4700 to λ 6000, the difference being greatest at λ 5500. In other words, as analysed in the spectroscope, the coronal light contains less blue and violet but more green and yellow than sunlight—an important point to bear in mind in discussions upon the polarisation of the corona and the question as to what proportion of its luminosity is due to light reflected from small particles.

M. Fabry made some careful and valuable measurements of the total and intrinsic light of the corona. For the former purpose he employed a Lummer photometer with a cell filled with an ammoniacal solution of sulphate of copper interposed between the standard light and the screen to harmonise the tints. His value for the total luminosity was 0·13 candle at one metre, which equals about three-quarters of the light of the full Moon, a result closely accordant with other recent determinations.

Some of the earlier observations gave very high values, ranging up to 25 full Moons, and must now be set aside. M. Fabry is of opinion that all the other values of any weight lie between 0·1 and 0·2 candle, while the full Moon is 0·175. He thus concludes that the average total intensity of the corona is not very different from, though probably slightly less than, that of the full Moon.

As regards the intrinsic illumination he found that the brightness at 5′ from the limb in the direction of the equator was equivalent to 720 candles per square metre as compared with 2600 candles for the full Moon, a ratio of 0·28 to 1, a value closely confirmatory of Professor Turner's ratio of 0·25 to 1.

The parties from the Lick Observatory were stationed at the two extreme ends of the line in Labrador and at Aswan. No observations were obtained at the western station, so that their hope of getting any photographic evidence of a change in shape of the corona during an interval of 2½ hours was not realised. Mr. Maunder was also in Labrador and was equally unfortunate.

Professors Campbell and Perrine were at Alhama, in Spain, where the weather was also cloudy.

Professor Todd was at Tripoli with a battery of cameras, the largest of which was provided with a lens of 12 inches aperture and was fitted with orthochromatic screen and a Burckhalter occulter. A number of photographs were secured.

The preliminary reports of the British parties have already been published (*Proc. R.S.* A No. 514) and we may here briefly summarise some of the more important results.

The weather conditions prevented either of the parties stationed in Spain—Mr. Evershed, at Pineda de la Sierra, or Professors Callendar and Fowler, at Castellon de la Plana—from obtaining any observations.

Sir N. Lockyer's party at Palma, Majorca, got only a partial view of the phenomenon through a break in the clouds towards the end of totality enabling some exposures to be made with the prismatic cameras and coronagraphs.

On the other hand Mr. Newall, at Guelma, was favoured by particularly good atmospheric conditions, and was able to carry out an extensive programme. A repetition of his previous attempt to determine the rotation of the corona by photographs of the "green" line with a double-slit spectroscope met with no better success than on the previous occasions, the light of the corona at 3′ from the limb failing to impress the photographic plate. His arrangements for attacking the problem of the polarisation of the coronal light were very complete, and comprised a "Savart" camera of 1·5 inch aperture, a "Nicol" camera of 2 inches aperture, and a polarising spectrograph. He also used an objective grating camera and two simple cameras.

The polarimeter observations will, when completely reduced, give quantitative values of the coronal polarisation, and they

show that the atmospheric polarisation was nearly horizontal and was about equal to the radial polarisation of the corona at $1\frac{1}{2}$ diameter from the limb.

The Astronomer Royal and Mr. Dyson were at Sfax, in Tunisia, equipped with the Thompson photographic telescope, giving an image on a scale of 4 inches to the Moon's diameter, another camera with the object glass of the astrographic equatorial, giving an image on a scale of $1\frac{1}{4}$ inch to the Moon's diameter, two small-scale cameras and two slit spectroscopes, used before in 1898, 1900, and 1901.

The photographs obtained with the Thompson coronagraph show interesting detail in the inner corona, especially remarkable being the oval rings, already alluded to, and the arched structures above the prominences. Mr. Dyson's photographs of the coronal spectrum show two new lines at λ 5536 and λ 5117.

Professor Turner, with Mr. F. A. Bellamy, was at Aswan, Egypt, where, with the exception of a slight haze due to dust, the state of the atmosphere was entirely favourable. He was accompanied by Mr. J. H. Reynolds, who was provided with a mirror of 2 feet aperture and 120 feet focal length, fed with light from a cœlostat of 28 inches diameter. The plates obtained with this instrument were unfortunately spoiled, owing to the grain of the wooden slides having impressed its image upon the film.

Professor Turner's observations were directed to the determination of the photographic intensity of the coronal light at varying distances from the limb and the quantitative measurement of the fraction of this light found to be radially polarised. A good set of plates was obtained, the complete measurement and reduction of which will be a matter of considerable labour.

In addition to the official British parties Professor L. Becker and Mr. Franklin-Adams were at Kalaa-es-Senam, Tunis, the former of whom made a series of exposures upon the corona for photometric purposes, the exposing apparatus being accurately controlled by a pendulum clock, while the latter secured some excellent direct views of the corona. Father Cortie also obtained successful photographs in Spain.

Besides the observers already mentioned there were many others, of whose work no detailed reports are yet to hand. Among these we may mention Professor Riccò and Mr. Rotch ; parties from the U.S. Naval Observatory in Spain ; parties of Russian astronomers in Spain and at Aswan, of German astronomers in Algeria and Spain ; members of the British Astronomical Association at Burgos, and many others.

It is stated that there were altogether no less than eighty observing stations occupied, so that, in spite of partial failure due to clouds, there is still a large bulk of observations to be reduced and discussed.

Any general deductions as to the lessons of the eclipse must be deferred until we are in possession of more complete details.

E. H. H.

Solar Activity in 1905.

Sun-spots.—The Sun-spot record for 1905 showed a very remarkable contrast to that of the previous year. Very early in January a scattered stream of rather small faint spots was seen upon the Sun, which passed off at the west limb in the usual course without having displayed any feature at all remarkable. The group returned, however, in the next rotation under a very different guise. It was now one immense spot of complex structure, the largest single spot as yet photographed at Greenwich. This was the first of a succession of great Sun-spots easily visible to the naked eye. The group returned for the third time to the visible hemisphere on February 25. It was still very large, though greatly shorn of its former proportions. Four days later another great spot was seen; and in May, June, July, and August, and again in October and November, enormous groups have appeared on the Sun. During the earlier part of the year the solar activity, considered apart from these great groups, did not appear to be increasing very fast; but towards its end, and especially in the month of November, the groups of spots were very numerous as well as large, and formed two great belts across the Sun. The mean daily total area will probably work out as about double that for 1904, so that the tide of increase is in full flood. The increase in faculæ has also been very marked.

The mean latitude of the spotted area was about 14° or 15° from the equator—that is to say, the zone usually occupied at maximum has already been reached. E. W. M.

The Prominences.—The mean daily number of prominences, from observations made on 95 days during 1905, is slightly less than the previous year's record. This reduction of activity is confined to the southern hemisphere, which shows a very marked falling off, whilst the northern hemisphere has increased a little The figures obtained are as follows :—

	1904.	1905.
North hemisphere	4·92	5·20
South „	5·14	4·15
Total mean numbers per diem ...	10·06	9·35

The polar regions of the Sun have again been nearly quiescent, although the high latitude zones of activity have made a distinct advance towards the poles. These prominences were found to be most frequent between the parallels 65° and 70° in both hemispheres, and the limits of prominence-formation at the close of the year may be put at +75° and −75°.

The northern hemisphere has been especially active in metallic prominences, nearly 5 per cent. of the total number of northern prominences strongly reversing the sodium and magnesium lines; 3 per cent. only of the southern prominences were

metallic. This type of prominence has been entirely confined to the zones $+9°$ to $+35°$ and $-9°$ to $-35°$.

A remarkable eruption was observed on January 29, apparently directed from the centre of the great spot group then near to the east limb. This outburst was characterised by an entire absence of metallic reversals. Strongly metallic eruptions were, however, subsequently witnessed in the same spot region, notably one on February 2, recorded by Fowler in *Monthly Notices*, lxv. 513. In this case, as in a similar eruption seen by the writer on November 10, $9^h\ 15^m$ to $9^h\ 35^m$ A.M., the sodium, magnesium, and enhanced iron lines were brilliantly reversed for a short time on the bright background of the Sun's disc. It may be remarked that the magnetograph records of Greenwich and Stonyhurst Observatories show very minute disturbances on February 2 and on November 10 exactly synchronising with the active phases of the two eruptions. J. E.

Double Stars.

The same classification is adopted as in previous reports. The abbreviations are :—

M. N.: Monthly Notices R.A.S.
A. J.: Astronomical Journal.
L. O. B.: Lick Observatory Bulletin.
A. N.: Astronomische Nachrichten.

Observations—

L. O. B., No. 74. *W. J. Hussey*
L. O. B., No. 77. „
L. O. B., No. 81. „

} Four hundred new double stars found whilst at the Lick Observatory. These catalogues bring Professor Hussey's double stars up to 1200.

M. N., lxv. 7. *Rev. T. E. Espin.* A catalogue of seventy new double stars.

M. N., lxvi. 3. *Rev. T. E. Espin.* A catalogue of 51 new double stars and measures of 120 known pairs.

M. N., lxvi. 1. *Royal Observatory, Greenwich.* Measures of 433 double stars made in the year 1904 with the 28-inch refractor.

A. N., No. 4022. *J. A. Miller and W. A. Cogshall.* Measures of 102 stars found by the Leipzig observers in zone $+10°$ to $+15°$.

A. N., No. 4054. *H. F. Lau.* Measures of 82 pairs with a 6-inch refractor at Copenhagen.

A. N., No. 4056. *P. Sternberg.* Photographs of double stars taken at Moscow :—

Castor ...	...	1904·16	223°·8	5″·55
ξ Ursæ Maj.	...	1904·23	139·4	2·64
γ Virginis	...	1902·36	328·4	5·82
„		1903·28	328·3	5·82
„		1904·30	327·9	5·86

A. S. P., No. 101. *R. G. Aitken.* Measures of β 208 and β 524.

A. S. P., No. 102. *R. G. Aitken.* Measures of Σ 2481 BC and new companions to Σ 419, Σ 1000, Σ 1823.

Publications of the University of Pennsylvania, vol. ii. part 3. *E. Doolittle.* Measures of 1066 double and multiple stars made at the Flower Observatory with the 18-inch refractor during the years 1899 and 1905. A fine set of measures in continuation of those already published in vol. i.

Popular Astronomy, 1905 *February. W. W. Campbell. Castor* as a quadruple star—*i.e.* each visual component is a spectroscopic binary.

A. N., No. 4067. *H. Ludendorff.* On a remarkable change in the spectrum of ζ *Boötis.*

A. S. P., No. 101. *W. W. Campbell.* Variable velocity of *Sirius* in the line of sight.

Calculations—

L. O. B., No. 71. *R. G. Aitken.* Orbit of β 395, period 24·0 years.

L. O. B., No. 80. *R. G. Aitken. ξ Scorpii.* Observations during the years 1900–1904 lead to a period of 44·5 years—*i.e.* half the previously adopted period.

L. O. B., No. 84. *R. G. Aitken.* A catalogue of orbits of binary stars, distinguishing between the reliable and non-reliable orbits.

L. O. B., No. 71. *R. G. Aitken.* Note on 13 *Ceti* (Hough 212).

A. N., No. 4051. *W. Doberck.* Orbit of σ *Coronæ Bor.*, period 1679·2 years.

A. N., No. 3989. *W. Doberck.* Orbits of Σ 186, Σ 1785, Σ 1879, Σ 1888, Σ 2026, and OΣ 285.

A. N., No. 4063. *W. Doberck.* Orbits of τ *Ophiuchi* and γ *Centauri.*

A. N., No. 4064. *N. E. Nörland.* Orbit of ξ *Ursæ Majoris*, period 59·8 years.

Untersuchungen über das Doppelsternsystem 61 *Cygni*—1905 *Upsala. Osten Bergstrand.* A determination of the parallax

from his own photographic plates, and a general discussion of proper motion and relative motion. He clearly shows the connection of the two stars and deduces a final parallax $+0''\cdot2926 \pm 0''\cdot0073$. T. L.

Variable Stars.

Large additions to the list of variable stars continue to be a feature of astronomical work during the past year. For example, the official numbers assigned to variables for 1904 run up to at least 283, and in 1905 up to 106; while Professor E. C. Pickering announces (apparently in addition to the foregoing) 843 new variables in the smaller Magellanic cloud (*Harvard Circular*, No. 96). It seems certain that only a proportion of the known variables can now be followed up by observation through their changes, and hence, next to discovery, the close study of some particular class of variation or some particular star is often taken up.

Among such discussions we may refer to that of Dr. Meyermann, who considers that the variation of δ *Cephei* can have nothing to do with the obscuration by a satellite, but attributes the variation in light to a change of radiation in the two bodies forming the "star" consequent on their varying distance from one another (*Ast. Nach.* 3985).

Mr. J. H. Jeans, discussing Algol-type stars, thinks that gravitational instability has not hitherto been taken account of in calculating the density, and considers that nothing is known but the period of rotation; nothing can be inferred as to the structure or nature of the system (*Astrophysical Journal*, xxii. 2).

Mr. T. W. Backhouse has published a volume of his own observations of nearly fifty variables, made in the years 1866–1904.

An apparently new star in *Pegasus* (159, 1904) was discovered by Mr. Stanley Williams. This has been found from the Harvard photographs to have existed for some years and to be a variable star (*Ast. Nach.* 3973).

48 *Aurigæ*, discovered to be variable by Mr. T. H. Astbury, a member of the British Astronomical Association, is interesting on account of its brightness. It can be easily followed in a binocular. Variation, $5^m\cdot0$ to $5^m\cdot6$. Period, probably about 3·8 days.

Another interesting discovery is that of the Algol-type variable *W. 2 Tauri*, made at Harvard College Observatory from photographs. The variation is unusually large, viz. from $7^m\cdot14$ to 11^m; period, 2·77 days. The amount of variation is greater than that of any other Algol-type star known (*Harvard Circular*, No. 104). E. E. M.

New Reduction of Groombridge's Catalogue.

An extraordinary amount of energy has been devoted for some years to the first reduction, re-reduction, revision, or re-observation of old collections of star places.

The following have already been published : the re-reduction of Bradley, Mayer, and Pond (1811–19) ; the revision of Taylor ; the reduction of Bessel's observations with Dollond's transit and the circle of Cary ; the Paris Catalogue, containing the meridian observations from 1837–81 ; several Cape Catalogues of an early epoch ; the revision of Lamont's *Zones* ; Bossert's *Supplément à l'Histoire Céleste* ; Auwers's *Fourteen Unknown Zones of Bessel* ; Weiss's new edition of Argelander's *Southern Zones* ; the re-observation of Piazzi.

An early publication of the following may be expected : the re-reduction of Piazzi's own observations ; of those of Henderson in Edinburgh ; of Plantamour in Geneva ; of Rümker's, Lalande's, and the Washington zones ; a revised edition of Argelander's *Northern Zones* ; the re-observation of Schjellerup's stars ; and probably a few others.

At the same time the *Geschichte des Fixsternhimmels*, started in Germany, and which inspired or stimulated several of the above-mentioned works, has begun to make an exhaustive collection of all the accurate meridian observations made between 1750 and 1900. This work, when finished, will give all the data relating to any one of the stars in the most complete and convenient form.

The effect of this vast amount of work will be (the words were applied by Auwers to the last-mentioned work exclusively) "to ensure to sidereal astronomy the permanent possession of all the riches gained by the combined efforts of the observers and computers engaged in meridional work during the 150 years which sever the beginning of the twentieth century from the beginning of meridian work of precision."

The importance of the older collections of observations evidently lies in their value for the derivation of proper motion. Those derived from a comparison of Bradley's observations with modern catalogues have been in the past the main material in the treatment of sidereal problems ; but Bradley's telescopes had apertures of only about $1\frac{1}{2}$ inch, and hardly any star in his catalogue is fainter than 7th magnitude. The consequence is that for the fainter stars, between magnitudes 7 and 9, we have mainly to rely on comparisons of the older zone observations of Lalande, Bessel, Lamont, &c., with the Catalogue of the Astronomische Gesellschaft. Precious as the data are which these comparisons furnish, they cannot in any way compare with the proper motions of the Bradley stars.

To see how inadequate they are to the demands of investigators in sidereal astronomy it is sufficient to consider that it is

hardly possible to derive from this material, in a satisfactory way, either the average proper motion of the stars between $7^{m}\cdot0$ and $9^{m}\cdot0$, or the percentage of proper motions above or below the average. On the other hand, the time is rapidly approaching when photography will furnish numerous accurate proper motions of stars fainter than the 9th magnitude. Any source yielding numerous accurate proper motions of stars between magnitudes 7 and 9 must therefore be doubly welcome.

Among these the catalogues of Piazzi and Groombridge stand foremost, and their re-reduction and re-observation have been a long-recognised *desideratum*. The latter work has now been completed. The observations of Groombridge (1806–1816) have been re-reduced wholly *de novo*, with the exception only of the conversion of the original readings of the microscopes, which seem to be lost, into readings of zenith distance.

The main difficulty in the way of a fundamental reduction of the right ascensions arose from the fact that "most of the stars within 10° of the Pole were observed within the first two years, and, generally speaking, it seemed as though Groombridge from time to time made lists of say a hundred stars or so, which, as soon as he had obtained some five observations, he struck off and never re-observed."

The consequence has been that practically only the observations of right ascension made in 1807 could be reduced fundamentally. For this period standard positions of *Polaris* were derived from consecutive upper and lower transits, and of other stars from Groombridge's observations on nights on which *Polaris* was also observed. Where these were still found "insufficient to give azimuth errors for every day's observation, supplementary lists of stars whose places depend on observations on days on which some of the standard polars were also observed were drawn up, and these stars, where necessary, have been used for the determination of azimuth error."

For the other years this "attempt to make Groombridge's right ascensions practically fundamental could not be sustained," and the azimuth error had, to a great extent, to be derived from the positions of stars contained in Newcomb's Fundamental Catalogue. No appreciable systematic error appears to have been introduced by this difference in treatment.

Even for a differential reduction there remained great difficulties. In regard to the right ascensions the main difficulty consisted in the want of materials for separating the collimation error from the azimuth error, so that the correction formula $m+n\tan\delta$ had to be used instead of $m+n\tan\delta+c\sec\delta$. In regard to the North Polar distances, which were all reduced strictly differentially by using all the Newcomb stars observed on each night for the derivation of the polar points, the chief difficulty lay in the determination of division errors.

The effect of the first difficulty has been greatly reduced "by the small limits of N.P.D. within which Groombridge usually

chose his stars for a night's observation," and by taking "all stars between 35°–52° N.P.D. for which reliable places could be found as adjuncts to the clock-error."

The determination of the division errors was successfully made by a comparison with the positions in Newcomb's Fundamental Catalogue. As the instrument was reversible and there were two circles, the two positions of the independent corrections for the same distances from the zenith were between 25° and 52°. For N.P.D. 10° to 25° a single determination was obtained, whereas the division errors for the few stars within 10° of the Pole had to be neglected for want of sufficient materials for their determination.

That both the difficulties for the right ascensions and the declinations have been overcome with a considerable degree of success appears best, perhaps, in the former case by the agreement of the values Groombridge-Newcomb for the faces east and west; in the latter by the agreement of those division errors for which two independent determinations were obtained.

Proper motions have been derived for every star by combining Groombridge's observations with modern Greenwich Catalogues, mainly with the Second Ten-Year Catalogue, Epoch 1890, giving an average difference of epoch of about eighty years.

These proper motions, the accuracy of which would seem to be of the order of those of Auwers-Bradley, constitute the main result of the whole work.

The intermediate positions of Radcliffe 1845 and the Catalogues of the Astronomische Gesellschaft have been compared, but have only served in the derivation of proper motion in very exceptional cases.

The authors have availed themselves of these new materials to get a new determination of the constant of precession and of the elements of the solar motion in space. They are led to a somewhat unexpectedly large correction of Newcomb's precession—viz. an increase of $\frac{1}{10000}$th part of the whole. They further derive a series of values for the positions of the apex for stars of different spectrum, different amount of proper motion, and different magnitude, which finally are united in the concluded position

$$A = 275° \qquad D = +37°.$$

The main advantage of these determinations lies in the fact that the motions on which they rest consist largely of new material. On the other hand, they labour under the drawbacks that this material "is confined to a very limited region of the sky" and that "the large relative preponderance of stars of large proper motion about 12^h of right ascension" . . . [which brings clearly out the well-known fact that the apparent motions of the stars in high galactic latitudes are greater on an average than those of stars in or near the Milky Way] "may well affect the determination of the position of the apex."

The Introduction further shows the distribution of the proper motions according to magnitude, amount of proper motion, and spectrum, in an extremely clear, concise, and complete way, which will command the gratitude of any investigator of stellar motions ; and the Catalogue, by the number of accurate proper motions of small stars which it contains and the care bestowed on its reduction, may safely be considered as the most valuable contribution of material for the study of sidereal motions since the publication of the third volume of Auwers-Bradley.

The Greenwich Observatory, and in particular Messrs. Dyson and Thackeray, are cordially to be congratulated on the successful conclusion of this great work. J. C. KAPTEYN.

Second Meeting of the International Union for Co-operation in Solar Research.

At the first meeting, held at St. Louis on 1904 September 23 (of which a brief account is given in the last Council report), Oxford and Meudon were suggested as places for the next meeting. The Executive Committee accepted the invitation to meet in Oxford, which was accompanied by a hospitable offer on the part of the Warden and Fellows of New College to entertain the foreign delegates.

The Executive Committee met to arrange a provisional programme on Monday, September 25, and the Union sat for scientific discussions on the mornings of September 27, 28, and 29 ; and for discussion of the proposed constitution on the afternoon of September 27. Among the chief decisions arrived at were the following :—

(*a*) A definite procedure was settled for the adoption of standard wave-lengths. The wave-length of a suitable spectroscopic line is to be fixed permanently, thereby defining the unit of wave-length. A committee was appointed to select secondary and tertiary standards.

(*b*) A standard instrument (Ångström's pyrheliometer) was adopted for the measurement of solar radiation, and a committee was appointed to draw up a scheme for promoting co-operation.

(*c*) General principles were laid down for guidance in schemes of co-operation in different branches of solar work ; and it was determined to select in the first instance the two following branches of research for special attention by the Union :—

(1) The study of the spectra of sun-spots.
(2) The study of the records, by means of the H and K light, of phenomena of the solar atmosphere.

Twenty-five actual delegates, and a dozen or more interested visitors, were present at the meeting. The next meeting was fixed for about September 1907 at Meudon, the actual date to be

decided by the Executive Committee (Professors Schuster and Hale, with a third member to be appointed by the International Association of Academies). H. H. T.

The Astrographic Catalogue and Chart.

In last year's report it was stated that the weak link in the chain was the zone from 17° to 40° south declination, which appeared to be making slow progress. This, happily, seems in a fair way of being remedied, in part at least, for the Santiago Observatory, to which the zone 17° S. to 23° S. was originally allotted, but which had been seriously hampered in its work, first by the death of its director, Professor Maturana, and then by want of money owing to political troubles, is now in more satisfactory circumstances; and by direction of M. Obrecht, the present director, his chief assistant, M. Ernesto Greve, has visited European observatories during the past year to learn details of the work preparatory to beginning the zone. There is no specific information from M. Thome at Cordoba, who is undertaking the next zone southward—*i.e.* from 24° to 31°—but the state of the work in the zones between this and the South Pole can be learned from the reports of the Observatories at Perth, the Cape of Good Hope, Sydney, and Melbourne, who share this area. M. Valle, of Tacubaya, has lately reported that for the zone for which he is responsible—10° S. to 16° S.—1000 Catalogue plates have been taken, and that a zone of declination one degree broad is nearly reduced.

The work on the zones of the northern hemisphere of the sky is proceeding on the lines given in former reports. The second volume of the rectangular co-ordinates of stars measured at Greenwich is being printed, and more than two-thirds of this is in type, which completes about five-sixths of the Greenwich zone. Funds have been supplied for printing the Oxford measures, and this work is in hand. The only publication during the year was the first volume of the zone undertaken by the Bordeaux Observatory, which gives the rectangular co-ordinates of the stars measured on the plates whose centres are at declination 17° N., exactly in the form adopted by the other French observatories. The introduction to this volume contains discussions by M. Rayet, the director, on various points, such as the accidental error of measurement due to the shape of the images and on other sources of error to which results are liable. There is also a memoir by M. Kromm on the *rattachement* of plates, illustrated by measures of a series of plates covering the *Pleiades* area, with a catalogue of the places of 196 stars of the group deduced from photographs.

The enlargement of the Chart plates before described is being continued. The number of reproductions now distributed

to date (February 1) is:—Paris, 222 ; Algiers, 207 ; Toulouse, 107; San Fernando, 46 ; Bordeaux, 40 ; Rome, 3 ; Greenwich, 322.

H. P. H.

Stellar Spectroscopy in 1905.

Nebulæ.—Dr. J. Hartmann's monochromatic photographs of the *Orion* nebula (*Astroph. Jour.* xxi. 389) show that the light which is effective in giving photographic portraits of such a nebula is very different in different parts of the nebula. The extraordinary intensity of the light of wave-length λ 3727—the existence of which was first proved in 1881 by Sir William Huggins—again draws attention to the need for the discovery of the origin of this light. Dr. Hartmann's observations point to the presence of at least three gases which contribute luminosity to the nebula.

New Stars.—Professor E. C. Pickering gives reasons (*Harvard Circular*, No. 99 ; *Astroph. Jour.* xxii. 90) for regarding *RS Ophiuchi* as a Nova rather than as a long-period variable star. "Its proper designation will be Nova *Ophiuchi*, No. 3, the new stars of 1604 and 1848 having also appeared in the same constellation."

Nova *Aquilæ*, No. 2. Professor Pickering announces (*Harvard Circular*, No. 106 ; *Astroph. Jour.* xxii. 271) the discovery by Mrs. Fleming of a second Nova in *Aquila*, and gives a brief description of its spectrum.

Messrs. Moore and Albrecht give a short note on the spectrum of Nova *Aquilæ*, No. 2 (*Pub. Astr. Soc. Pac.* xvii. 156).

Professor W. H. Julius discusses (*Astroph. Jour.* xxi. 286), from the point of view of anomalous dispersion, the bands in the spectrum of Nova *Persei*.

A portfolio of photographs of the spectrum of Nova *Persei* by the late Frank McClean has been published by Stanford, London. It contains six plates of enlarged spectra, and also reprints of Mr. McClean's notes published in the *Monthly Notices*, together with a short note by Mr. Newall on the later photographs.

Classification of Stellar Spectra.—Sir Norman Lockyer contributes (*Proc. R. S.* vol. lxxvi. 145) further experimental evidence about the relative distributions of energy in the spectra of different stars. The difficulty of reasoning upon data of this kind is well exemplified by the conclusions with which the note ends.

Dr. W. E. Wilson (*Proc. R. S.* vol. lxxvi. 374) gives general considerations on the evolution of the spectrum of a star during its growth from a nebula, and these lead him to the conclusion that "it would seem impossible to classify stars on a scale of temperature alone."

Studies of Special Stars.—Professor E. C. Pickering communicates two lists of stars having peculiar spectra, and also a table of spectra of known variables (*Harvard Circular*, Nos. 92 and 98; *Astroph. Jour.* xxi. 292 and xxii. 87).

Herren Ludendorff and Eberhard describe (*Ast. Nach.* 170, 165) remarkable peculiarities observed in the spectrum of *ζ Boötis*.

Sir Norman Lockyer remarks upon the spectrum of *μ Centauri* (*Proc. R. S.* lxiv. 548).

Radial Velocity of Stars.—Professor H. C. Lord (*Astroph. Jour.* xxi. 297) gives results for thirty-two stars studied at the Emerson McMillin Observatory.

Mr. Slipher (*Astroph. Jour.* xxii. 318) has given evidence of the efficient nature of the spectrograph at the Lowell Observatory. In a list of results for ten stars selected in the plan of co-operation between various observatories he gives also a summary of results obtained by different observers. In a further note (*Astroph. Jour.* xxii. 84) he publishes a summary of observations of the variable velocity of *γ Geminorum*.

Mr. Newall (*Monthly Notices R.A.S.* lxv. 651) summarises the results obtained at Cambridge Observatory for nine selected stars in 1903.

M. Belopolsky (*Astroph. Jour.* xxi. 55) gives details of measurements of photographs of *α Boötis*.

Variable Radial Velocity.—The Lick Observatory *Bulletin*, No. 79, contains, under the title "First Catalogue of Spectroscopic Binaries," a list of 140 star systems of which the composite nature had been discovered or verified by spectroscopic observations before 1905 January 1. In a final note reference is made to four other discoveries made after that date. The catalogue contains details of magnitude and spectral type of each of the stars named; period and other orbital data are given for about fifty stars. The notes as to discoverer and references which complete the data show what a splendid contribution the Lick observers have made to our knowledge of these multiple systems.

Professor Campbell and Mr. H. D. Curtis give details (*Astroph. Jour.* xxi. 185) of variable velocity for *α Andromedæ*, *ζ Ceti*, *γ Geminorum*, α_2 *Geminorum*, *η Boötis*, *ξ Serpentis*, *ζ Lyræ*, *τ Sagittarii*, and 71 *Aquilæ*. The same authors give further information (*Astroph. Jour.* xxi. 191) relating to *Polaris*, *η Piscium*, *ε Aurigæ*, and *β Orionis*.

Professor Campbell contributes (*Astroph. Jour.* xxi. 176) a very interesting note on the variable velocity of *Sirius*.

Mr. W. H. Wright gives (*Astroph. Jour.* xxi. 371) notes of variable velocity detected in the Southern Hemisphere in the case of *α Phœnicis*, *γ Phœnicis*, θ_1 *Eridani*, *X Eridani*, *δ Columbæ*, *A Carinæ*, *σ Puppis*, *α Puppis*, *α Volantis*, *α Carinæ*, *κ Velorum*, and *p Velorum*.

Professor Frost gives a note (*Astroph. Jour.* xxii. 213) on observations of certain variable stars (chiefly of the *Algol* type), viz. *R Canis Majoris*, *Z Herculis*, *U Sagittæ*, *U Ophiuchi*, *RX Herculis*, *Y Cygni*, and *R Coronæ*.

Mr. R. H. Curtiss contributes a note (*Astroph. Jour.* xxii. 274) on the light- and velocity-curves of *W Sagittarii*.

Mr. Slipher in a note (*Astroph. Jour.* xxii. 84) deals with the velocity of γ *Geminorum*.

Professor W. H. Julius makes (*Astroph. Jour.* xxi. 286) a new suggestion, from the point of view of anomalous dispersion, about the appearance of variation in the velocity of δ *Orionis*.

Orbits of Spectroscopic Binaries.—Mr. W. S. Adams has calculated (*Astroph. Jour.* xxii. 115) the orbit of ζ *Tauri* from twenty-five spectrographic determinations of its velocity at the Yerkes Observatory.

Solar Parallax from Spectrographic Observations of Stars.—Professor Küstner has deduced (*Ast. Nach.* **169**, 241) a value of the solar parallax from eighteen spectrograms of *Arcturus*, obtained at the Bonn Observatory with a spectrograph attached to the 12-inch equatorial. The value obtained is $8''{\cdot}844 \pm 0''{\cdot}017$.

Standards of Wave-length.—At the meeting of the International Union for Co-operation in Solar Research, held at Oxford, 1905 September 27–29, it was decided to embark upon a series of new determinations of standard wave-lengths (*Astroph. Jour.* xxii. 276).

New Spectrographic Installation.—Mr. Newall (*Monthly Notices R.A.S.* lxv. 636) describes the four-prism spectrograph which has been used at Cambridge Observatory for stellar work since 1899.

Design of Stellar Spectrographs.—In a paper on "The Optics of the Spectroscope" (*Astroph. Jour.* xxi. 197) Professor Schuster deals with the question of slit width, purity of spectrum, and intensity.

In a paper on the design of spectrographs for large equatorials (*Monthly Notices R.A.S.* lxv. 608) Mr. Newall gives details of the diffractional method of estimating slit-widths; and after dealing with the effects of atmospheric tremor on star images he considers the question of the brightness of the photographed spectra under specified conditions of purity and linear dispersion with equatorials of different aperture.

Interpretation of Spectra.—A paper of high interest and importance has been published by Professor A. Schuster on Radiation through a foggy atmosphere (*Astroph. Jour.* xxi. 1). The author takes account not only of absorption but also of scattering of light.

H. F. N.

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

His Majesty's Government in India.
His Majesty's Secretary of State for the Colonies.
His Majesty's Secretary of State for India.
The Lords Commissioners of the Admiralty.
The French Government.
The Italian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Geological Society of London.
Meteorological Office.
National Physical Laboratory.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
Solar Physics Observatory.
University College, London.
Birmingham, Midland Institute Scientific Society.
Cambridge Observatory.
Cambridge Philosophical Society.
Cardiff, Astronomical Society of Wales.
Chatham, Royal Engineers' Institute.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Galway, Queen's College.
Leeds Astronomical Society.
Liverpool Astronomical Society.
Liverpool Literary and Philosophical Society.
Liverpool Observatory.
Manchester Literary and Philosophical Society.
Oxford, Clarendon Press.

Oxford University Observatory.
Rugby School Natural History Society.
Stonyhurst College Observatory.
Truro, Royal Institution of Cornwall.
Abbadia Observatory.
Adelaide, Government Observatory.
Algiers Observatory.
America, Astronomical and Astrophysical Society.
Amsterdam, Dutch Eclipse Committee.
Amsterdam, Royal Academy of Sciences.
Arcetri, Royal Observatory.
Australasian Association for the Advancement of Science.
Basel University.
Batavia, Royal Magnetical and Meteorological Observatory.
Batavia, Royal Society of Natural History.
Berlin, German Physical Society.
Berlin, Institute of Computation of the Royal Observatory.
Berlin, Royal Observatory.
Berlin, Royal Prussian Academy of Sciences.
Berne University.
Bologna, Royal Academy of Sciences.
Bologna, University Observatory.
Bombay Branch of the Royal Asiatic Society.
Bordeaux Observatory.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Brisbane, Royal Geographical Society of Australasia.
Brussels, Belgian Astronomical Society.
Brussels, Royal Academy of Sciences of Belgium.
Buda-Pesth, Hungarian Academy of Sciences.
Calcutta, Asiatic Society of Bengal.
Canada, Department of Marine.
Canada, Geological Survey.
Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Catania, Italian Spectroscopic Society.
Catania, Royal Observatory.
Charkow, University Observatory.
Cherbourg, National Society of Sciences.
Christiania, Norwegian Geodetic Commission.
Cincinnati Observatory.
Coimbra, Polytechnic Academy.
Colorado College Observatory.
Copenhagen Observatory.
Copenhagen, Royal Danish Academy of Sciences.
Cracow, Academy of Sciences.
Dijon, Academy of Sciences.
Egypt, Survey Department.

Geneva Observatory.
Geneva, Society of Physics and Natural History.
Göttingen, Royal Observatory.
Göttingen, Royal Society of Sciences.
Granada Observatory.
Groningen, Astronomical Laboratory.
Hamburg Observatory.
Harvard College Astronomical Observatory.
Heidelberg, Astrophysical Observatory.
Helsingfors, Central Meteorological Institute.
Helsingfors, Finnish Society of Sciences.
Hong Kong Observatory.
India, Survey Department.
International Bureau of Weights and Measures.
International (Central) Geodetic Bureau.
Kalocsa, Haynald Observatory.
Kasan, Imperial University.
Kiel, University Observatory.
Kodaikánal Observatory.
Königsberg, Royal University Observatory.
Leiden Observatory.
Leipzig, Astronomical Society.
Leipzig, Royal Society of Sciences of Saxony.
Lick Observatory.
Lisbon Observatory.
Lowell Observatory.
Lund, Astronomical Observatory.
Madrid, Astronomical Observatory.
Madrid, Royal Academy of Sciences.
Manila, Philippine Weather Bureau.
Mauritius, Royal Alfred Observatory.
Melbourne Observatory.
Milan, Royal Observatory.
Missouri University, Laws Observatory.
Moncalieri Observatory.
Montpellier, Academy of Sciences.
Moscow, Imperial Society of Naturalists.
Munich, Royal Bavarian Academy of Sciences.
Naples, Royal Academy of Sciences.
Natal Observatory.
New York, Columbia College Observatory.
Nice Observatory.
Nova Scotian Institute of Sciences.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Ottawa, Royal Society of Canada.
Padua, Astronomical Observatory of the University.
Palermo, Royal Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.

Paris, Bureau of Longitude.
Paris, École Polytechnique.
Paris, International Astrophotographic Congress.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society.
Perth Observatory, Western Australia.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Philadelphia University, Flower Observatory.
Pola, Imperial Hydrographic Office.
Potsdam, Central International Geodetic Bureau.
Potsdam, Royal Prussian Geodetic Institute.
Prague, Imperial Observatory.
Pulkowa Observatory.
Rio de Janeiro Observatory.
Rome, Italian Society of Sciences.
Rome, Royal Academy dei Lincei.
St. Petersburg, Imperial Academy of Sciences.
San Fernando, Observatory of Marine.
San Francisco, Astronomical Society of the Pacific.
Santiago, National Astronomical Observatory.
São Paulo, Sociedade Scientifica.
Stockholm Observatory.
Stockholm, Royal Swedish Academy of Sciences.
Strassburg, Imperial University Observatory.
Sydney Observatory.
Tachkent, Astronomical and Physical Observatory.
Tacubaya, National Astronomical Observatory.
Tokyo, Astronomical Observatory.
Toronto, Canadian Institute.
Toronto, Royal Astronomical Society of Canada.
Toronto University.
Toulouse, Academy of Sciences.
Toulouse, Astronomical Observatory.
Transvaal Meteorological Department.
Turin, Royal Academy of Sciences.
Turin, Royal Observatory.
Uccle, Royal Observatory of Belgium.
United States Coast and Geodetic Survey.
Upsala Observatory.
Upsala, Royal Society of Sciences.
Utrecht, Royal Meteorological Institute.
Vienna, Imperial Academy of Sciences.
Vienna Imperial Geodetic Bureau.
Vienna, Imperial Military Geographical Institute.
Vienna, Imperial University Observatory.
Vienna, Von Kuffner Observatory.
Wanganui Astronomical Society.
Washington, Carnegie Institution.

Washington, Navy Department.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Naval Observatory.
Yale University, Astronomical Observatory.
Yerkes Observatory.
Zürich, Central Meteorological Institute of Switzerland.
Zürich, Natural History Society.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Indian Engineering."
Editor of "Nature."
Editor of "Naturwissenschaftliche Rundschau."
Editors of "The Observatory."
Editors of "Popular Astronomy."
Editor of "Sirius."

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ADDRESS

Delivered by the President, Mr. W. H. Maw, on presenting the Gold Medal of the Society to Professor W. W. Campbell.

The Gold Medal of the Royal Astronomical Society has this year been awarded to Professor William Wallace Campbell "for his spectroscopic researches, which have greatly increased our knowledge of stellar motions"; and it is my pleasant duty to-day to lay before you some particulars of the work which our Medallist has carried on with such persistent energy, and with most marked success, for so many years past.

The determination of stellar velocities in the direction of the line of sight is a branch of astronomical research which has engaged the attention of such a comparatively small band of workers that I may perhaps be allowed—even when speaking to an audience like the present—to devote a few moments to a brief sketch of its history and development. As is well known, the determination of radial velocities depends upon the fact, pointed out by Doppler as long ago as 1842, that the wave-length of light reaching the eye is affected by the motion of the source of light in the radial direction. A few years later, in 1848, Fizeau showed that the lines of the spectrum could be turned to account to determine the changes of refrangibility due to motion of the light source; but it was not until 1866 that steps were taken to utilise this fact for the measurement of stellar velocities in the line of sight. In that year the matter was taken in hand by Sir William Huggins; and having in the following year succeeded in devising and constructing suitable instrumental arrangements, he was able in 1868 to contribute to the Royal Society a paper giving the results of observations on the displacement of the F line in the spectrum of *Sirius*, thus laying the foundations of a new branch of astronomical research, which has since yielded such valuable and far-reaching results.

In 1871 observations of radial velocity were taken up by Vogel at Bothkamp, while Huggins continued to improve his equipment and increase the number of stars observed by him. The work was also taken up at Greenwich, where many observations were made by Maunder, and at Rugby, by Seabroke. In all these cases the observations were made visually, and the

difficulties attendant upon the measurement of the shift of the lines were so great that the results obtained varied very widely, and it was felt generally that the velocities deduced were not such as to inspire entire confidence in their accuracy.

This state of affairs continued until, in 1888, a very decided step in advance was made at Potsdam by H. C. Vogel, who, in place of continuing the visual observations, arranged to measure the displacement of lines in stellar spectra which had been recorded by photography. This change in the mode of working possesses many important advantages. By the use of prolonged exposures it renders available for measurement faint spectra with which it would be practically impossible to deal visually; while the measures can be made at leisure, under convenient conditions, and can be repeated as desired. On the other hand, the photographic method of working has difficulties of its own of no mean order, and the attainment of successful results by it involves in a very high degree the possession of skill, experience, and patience on the part of the worker.

One of the earliest results of the employment of the photographic method of observing stellar spectra was the discovery of the class of stars now generally known as spectroscopic binaries. For convenience it is common to speak of these binaries as divided broadly into two classes: namely, first, those in which each of the components is sufficiently bright to yield a spectrum which can be observed and measured; and, second, those in which one of the components is either dark, or so faint that the spectrum of one only of the components can be recorded with the instruments available. Strictly, of course, these two classes are not distinct, there being all gradations of intermediate pairs, representing different proportions of brilliancy of the two components; but the classification has, nevertheless, its convenience, as it indicates the difference in the methods by which the pairs can be observed. In stars of the first class the difference between the movements in the line of sight of the two components is indicated by the shift of the lines of one spectrum relatively to those of the other; and the measurement of this shift (and consequently of the radial movement corresponding to it) is thus quite independent of the radial motion which the system as a whole may have relatively to the Earth. Pairs of this class can thus be observed by the aid of slitless spectroscopes, such as the object-glass prism, the orbital motion of the two components being indicated by the periodical doubling and undoubling of certain lines in their spectra.

In the case of the second class of spectroscopic binaries, on the other hand, the determination of the orbital motion depends upon the measurement of the variable radial motion of the bright component in the line of sight relatively to the Earth; and this necessitates a comparison of the stellar spectrum with the spectrum of an artificial source, in order that the shift of certain lines, due to the radial motion of the star, may be

measured. It is evident, of course, that unless the motion of the star at any given moment relatively to the Earth can be ascertained with a high degree of accuracy, it will be quite useless to attempt to deduce the orbital motion of a spectroscopic binary from any variation in such measured movement. The development of this branch of spectroscopic astronomy has thus only been secured by the gradual introduction of various instrumental refinements, combined with the recognition of the sources of error, and the exercise on the part of the observers of care and skill of the very highest order. Amongst those who have contributed to this progress none are entitled to a higher place than he to whom your medal has this year been awarded. Of course the discovery of spectroscopic binaries is in no sense the primary object of the measurement of radial velocities; but the fact that binary pairs of this second class can now be effectively dealt with is in itself a proof of the advances which have been made.

The first spectroscopic binary to be discovered was *ζ Ursæ Majoris*. In the third Annual Report of the Henry Draper Memorial, issued in 1889, Professor Pickering called attention to the fact that in the spectra of the star photographed at Harvard the K line occasionally appeared double. Photographs of the spectrum taken at intervals extending from 1887 March to 1889 October were carefully examined by Miss A. C. Maury; and eventually evidence was obtained pointing clearly to the conclusion that this doubling of the K line was due to the orbital motion of a pair of bodies giving spectra of the same type and of approximately equal brightness. *ζ Ursæ Majoris* thus belongs to the first-named class of spectroscopic binaries, and its discovery was closely followed by a second—namely, that of *β Aurigæ*, Miss Maury announcing, late in 1889, that lines in the spectrum of this star became alternately double and single every forty-eight hours, thus giving the pair a period of four days.

The first spectroscopic binary of the second class to be discovered was *Spica* (*α Virginis*), the duplicity of which was announced in 1890 by Dr. Vogel, who had during the previous year determined spectroscopically variations in the radial velocity of *Algol* (*β Persei*), and had thus endorsed the deduction of its binary character founded on observations of its varying luminosity. From that time the discovery and examination of close binary systems by spectroscopic means have gone steadily on, and admirable work has been done, notably in Europe, by Vogel and Scheiner at Potsdam, Belopolsky at St. Petersburg, Newall at Cambridge, and Deslandres at Meudon; and on the other side of the Atlantic by Professor Pickering and his colleagues at Harvard, by Frost and Adams at the Yerkes Observatory, by Slipher at the Lowell Observatory, and lastly—but in this case certainly very far from least—by Professor Campbell and his colleagues at Mount Hamilton. At the present date the number

of known spectroscopic binaries amounts to some 146, and of these nearly one-fourth have, as we shall see later, been discovered by our Medallist personally.

The measurement of stellar velocities in the line of sight by visual methods was taken up at the Lick Observatory some fifteen years ago, when measures were made by the late Professor Keeler, and subsequently by Professor Campbell and Dr. Crew. It was at this period that the late Professor Keeler made, with a grating spectroscope, his magnificent series of measures of the radial velocities of fourteen nebulæ. This work was of the highest order, but the feebleness of light for visual measures led to work in this branch of research being discontinued ; and the determination of radial velocities cannot be said to have formed an item in the regular programme of work at Mount Hamilton until the construction of the Mills Spectrograph in 1895. The installation of this spectrograph, as well as its partial reconstruction some six years later in accordance with the experience then acquired, was rendered possible by the generosity of Mr. D. O. Mills ; and in designing it Professor Campbell determined to sacrifice any considerations which would interfere with its convenience and efficiency for the determination of stellar velocities in the line of sight, using the Hγ region of the spectrum. It would be impossible—even if it were desirable—in the time available to-day, to give anything like a detailed description of the Mills Spectrograph, and I must, therefore, confine myself to a few brief notes concerning it.

The Lick telescope has a clear aperture of 36 inches and a focal length of 58 feet, the focal length for the Hγ rays, however, being 1·9 inches longer than for the D rays, a fact which affected a certain feature in the design of the spectrograph, as will be seen later. The collimator of the spectroscope has a double lens of Jena glass, 1·78 inches clear aperture stopped down to 1·5 inches, and a focal length of 28·4 inches. It gives a circular beam of Hγ light, 1·5 inches in diameter, received by a train of three dense flint prisms of such density and angle as to give a total deviation of about 180 degrees.

As regards resolving power, the instrument has been found fully capable of realising the theoretical limits appropriate to its proportions. In the case of the solar spectrum the observed purity has for practicable slit widths been found somewhat greater than its computed value ; while in the case of some stellar spectra photographed on rapid plates, with a slit-width of 0·02 millimetre, lines λλ 4337·216 and 4337·414 are shown separated ; the difference in wave length—namely, 0·198 tenth-metre—being in these instances exactly the theoretical limit for the width of slit used.

The steepness of the colour curve of the object-glass of the Lick telescope, to which I have already referred, led to a difficulty in the guiding of the instrument when the spectrograph was in use. With the slit placed on the Hγ focus, the Hγ image

of a star is a point in the centre of a comparatively large disc of light due to rays of various refrangibilities, and the central point cannot be seen with sufficient distinctness to be used for guiding. This rendered inapplicable Sir William Huggins's simple plan of using reflecting slit plates. Other known methods had disadvantages of their own, and at length, after many experiments, Professor Campbell decided to use light reflected from the first prism surface to form a guiding spectrum, this reflected light passing through a thirty-degree prism to the guiding telescope. An occulting bar in the eyepiece covers all the spectrum except the Hγ region, this region being linear as the Hγ rays are in focus on the slit. If the Hγ image fails to be on the slit, a gap occurs in the guiding spectrum. This guiding device has proved quite satisfactory.

It is the practice at the Lick Observatory to use the big telescope for spectroscopic work on three nights in each week, the remaining nights being devoted to double-star work, &c. Provision had, therefore, to be made for readily and safely attaching and detaching the spectrograph, and the arrangements for this purpose have been so well worked out that the change from micrometer to spectrograph, or *vice versa*, can be easily effected by one person in six minutes.

I have said that the determination of the radial velocities of stars by the measurement of photographed spectra is a system of working attended with special difficulties of its own, and perhaps a few figures relating to the practice at Mount Hamilton may serve to show the delicacy and accuracy necessary. With the Mills Spectrograph an exposure of about fifteen seconds, with a slit width of 0·015 millimetre, will record the spectrum of *Sirius*, but for a fifth-magnitude star about an hour's exposure with a slit width of 0·025 millimetre is necessary under average conditions. The width of the spectrum obtained is about 0·3 millimetre. The comparison spectra used are those of hydrogen and iron, an exposure of five seconds sufficing for the Hγ line, while in the case of the iron spectrum about three seconds is given for the brighter, and about sixty seconds for the faint lines, a device being provided for occulting the brighter lines after a short exposure has been made.

The measurement of the spectra is effected by a micrometer microscope, which is a duplicate of that employed at Potsdam. It has a screw of 0·25 millimetre pitch, the head being divided into 100 parts, and being capable of being read to tenths of a division. Three settings are made on each of the star lines selected for measurement, and a corresponding number on the lines of the comparison spectrum, corrections being, of course, introduced for the curvature of the spectrum lines. Speaking of these measures, Professor Campbell has said : " The extreme accuracy required and attained in this class of work is evident from the following statement : The linear value of 0·01 second of arc in the focus of the 36-inch refractor is 0·000857 millimetre.

On the spectrum plates 0·000857 millimetre is 0·0034 revolution of the screw, corresponding to 0·74 kilometre per second displacement.* It is not surprising, therefore, that great care and considerable experience are absolutely necessary for suitable measurement of the plates. The lines to be measured require good judgment in their selection. Some of the best lines in the solar spectrum are practically useless in many stars, owing to the changed intensities of close companion lines."

From the measured displacement of the stellar lines the corresponding radial velocity can be calculated, but the velocity so obtained is that of the star relative to the observer at the time of the observation; and before the motion of the star relative to the sidereal system can be ascertained four components must be eliminated. These components are due (1) to the rotation of the Earth on its axis; (2) to the revolution of the Earth round the common centre of gravity of the Earth and Moon; (3) to the revolution of the Earth round the Sun; and (4) to the motion of the solar system as a whole. For determining this last correction we are not yet in possession of sufficient data, and the practice at present, therefore, is to reduce stellar radial velocities to the Sun by the application to the observed velocities of the three first-named corrections. The application of these corrections and other calculations relating to the spectroscopic determination of velocities have been much facilitated by a valuable series of tables prepared by our Medallist.† In an introduction to these tables, Professor Campbell says: "The remarkable accuracy of recent spectroscopic observations requires that the corrections be applied to the nearest tenth of a mile (= 0·16 kilometre) per second. The still greater accuracy which may be reasonably expected in the future will require that they be applied to one-hundredth of a mile (= 0·016 kilometre) per second, and such is the limit of precision adopted in these tables." The success which has attended our Medallist's own work in this direction seems to amply warrant the forecast made in the words I have just quoted.

The Mills Spectrograph was first used in 1895 May, but it was nearly a year later before all adjustments had been completed and sources of error eliminated. Between the summer of 1896 and the end of 1900 some 2000 spectrograms were obtained, these including some 1500 spectrograms of 325 stars situated between the North Pole and declination −30 deg. Of these last-named spectrograms between 300 and 400 related to spectroscopic binaries, nearly fifty plates being required for the investigation

* In other words, the displacement of a line corresponding to a velocity in the line of sight of 1 kilometre per second is equal to about $\frac{1}{865}$th of a millimetre, or, say, $\frac{1}{21600}$th of an inch.

† *Astronomy and Astrophysics*, vol. xi. p. 319. The Tables, modified to suit the adoption of the kilometre as the unit of velocity per second, are also given in Frost's translation of Scheiner's *Treatise on Astronomical Spectroscopy*, p. 338

of *ζ Geminorum* alone. Since that time the work has gone on steadily and with ever-increasing accuracy, and in April last year Campbell was able to bring out the first published catalogue of spectroscopic binaries : a catalogue which is in itself ample evidence of the importance of the work done by our Medallist.

From this catalogue it will be seen that at the end of 1904 140 spectroscopic binaries were known, and of these no less than fifty-eight had been discovered by the aid of the Mills Spectrograph at the Lick Observatory, and fourteen by the D. O. Mills Expedition to the Southern Hemisphere, making seventy-two, or more than half the total, discoveries stand to the credit of the Lick Observatory staff. The more recently constructed Bruce Spectrograph of the Yerkes Observatory makes an excellent second, with forty-one discoveries to its credit. Of the fifty-eight spectroscopic binaries discovered at Mount Hamilton up to the end of 1904 no less than half—twenty-nine—were discovered by Campbell himself, and five more by Campbell working in conjunction with another observer. During 1905 the number of binaries recorded in the catalogue just referred to has been increased by six, of which three have been discovered at the Yerkes Observatory, two at Mount Hamilton, and one at the Mills Observatory, Santiago. Up to the present the radial velocities of some 500 stars have been determined at Mount Hamilton, and of about 200 more by the D. O. Mills Expedition to Chile, and the whole of this extensive and most important work has been inaugurated by our Medallist, and carried out—much of it by himself personally—in accordance with the programme which he had drawn up.

Nor is the importance of our Medallist's work on the determination of radial velocities and the characteristics of spectroscopic binaries to be judged simply, or even chiefly, by its amount. Of even greater value is the influence which he has personally exerted on the accuracy of observations of radial velocity. Writing on this point in 1904, in the publications of the Yerkes Observatory, Professors Frost and Adams said : "The next great advance was made by Campbell, in his design of, and work with, the Mills Spectrograph of the Lick Observatory. . . . The use of iron as a comparison spectrum (previously tried by Vogel and Deslandres, but not regularly employed by them), together with the closest attention to the optical and mechanical construction of the instrument, and great refinement in the measurement of the plates, enabled Campbell to increase greatly the accuracy of the determinations ; so that the natural unit became the kilometre per second, instead of the sevenfold greater German geographical mile employed by Vogel."

Our Medallist's views as to the future development of this branch of spectroscopic work are naturally of great interest. Up to the end of 1904, he tells us, at least one in seven of the stars examined by the Mills Spectrograph appears to be an

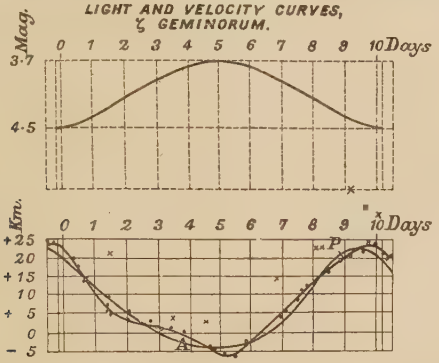
invisible binary of short period. In the case of the Bruce Spectrograph at the Yerkes Observatory, where stars of the "Orion" type have been especially studied, the proportion of binaries has been much greater—namely, about one in three.

It must be remembered, however, that the spectroscopic binaries, so far discovered, are naturally those having relatively short periods, and showing therefore considerable variations in velocity, the smallest variation so far recorded as showing a binary character being in the case of *Polaris*, namely, 6 kilometres per second. But much smaller variations than this may really be indicative of orbital motion; and there is every probability that, as time goes on and data accumulate, spectroscopic binaries may be numbered by thousands. One limit to our present investigations lies in the enormous loss of light in passing through a train of prisms, and in the fact that in the spectrum the light of a star is spread over a comparatively large area. Professor Campbell regards the 8th magnitude as probably the smallest which can be successfully observed by existing appliances, and he considers that obtaining the spectrogram of a 9th magnitude star using only moderate dispersion is comparable with photographing a 20th magnitude star by the aid of our most powerful reflecting telescopes.

If time permitted much could be said respecting the special features of many of the spectroscopic binaries which have been discovered by our Medallist, but I must content myself with some brief notes on three only. The first of these is ζ *Geminorum*, a well-known variable, which I have already had occasion to mention. Its binary character was discovered by Belopolsky in 1898 January, but no announcement of the discovery appears to have been published, and the duplicity of the star was independently discovered by Professor Campbell in 1899 January, and announced by him the following month. Between 1898 November and 1900 February forty-four spectrograms of ζ *Geminorum* were secured at Mount Hamilton, and these were duly measured and reduced, with the result that they showed clearly that the pair had an orbital movement corresponding to the period of its light curve—namely, 10·154 days, the observed velocity in the line of sight varying from $+24{\cdot}2$ to $-6{\cdot}7$ kilometres per second.

The diagram on page 253 shows in the upper figure the light curve of ζ *Geminorum*, and in the lower figure the radial velocities, the thick line showing the velocities as observed, and the thin line the velocities corresponding to an elliptic orbit, which Professor Campbell selected as affording probably the best possible elliptic representation of the observed curve. The observations extend over forty-five complete periods, and it will be noted that the two curves intersect six times during a period. Professor Campbell has remarked that the disturbances in the observed curve might be explained by assuming that ζ *Geminorum* was a triple system, but he considers that they are more

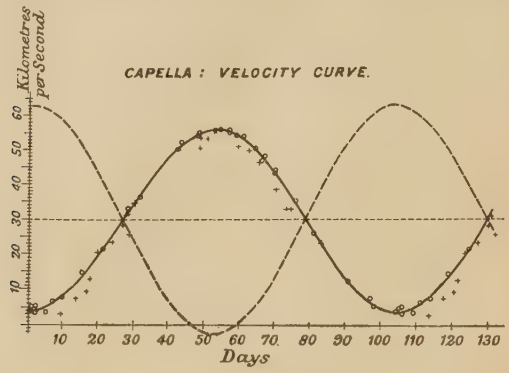
probably due to tidal effects caused by the comparative proximity of the two components revolving in an eccentric orbit.



The next spectroscopic binary which I shall mention, namely, *Capella*, has a special interest for British astronomers, inasmuch as its binary character was discovered independently by our Medallist at Mount Hamilton and by Mr. Newall at Cambridge within a very brief period, Professor Campbell making his announcement at the meeting of the Astronomical and Astrophysical Society of America in 1899 September, while Mr. Newall submitted a note on his discovery at the meeting of our Society in November of the same year. During 1900 also the pair was observed with the 28-inch equatorial at Greenwich, and a number of micrometer measures were made, with results pointing to an orbit closely agreeing with that deduced from spectrographic observations.

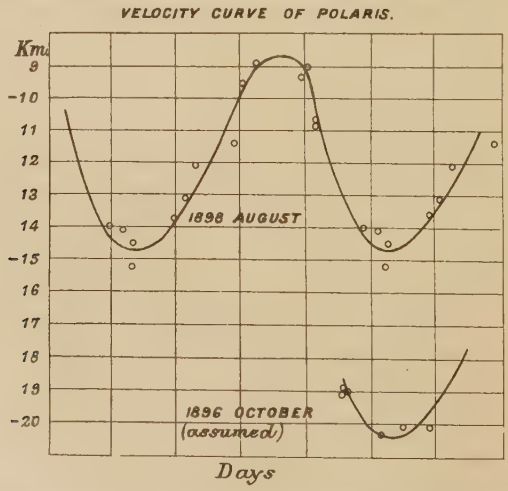
According to Professor Campbell the spectra of the two components are distinguishable on most of the spectrographs taken, that of the principal star being of the solar type, and that of the other something between the solar and Sirian types, and the presence of the latter spectrum adds materially to the difficulties of measuring that of the chief component. From data based on thirty-one spectrographs taken between 1896 September and 1900 September Campbell deduced for the chief component a range of velocity in the line of sight from +4·2 to +55·7 kilometres per second, and for the second component a range from −3 to +63 kilometres per second; while for the velocity of the centre of mass of the system he arrived at the value +30 kilometres per second. On computing the orbit, the period determined as best agreeing with the observations was one of 104·1 days, the orbit having an eccentricity of 0·02. The diagram on page 254 records these figures, and shows the computed velocity curve, abscissæ representing times and ordinates velocities in the line of sight, while the dotted horizontal line indicates the velocity of the centre of mass. The dotted curved

line indicates, approximately, the variable radial velocity of the lesser component.



On the diagram the Mount Hamilton observations are represented by circles, while Mr. Newall's observations are plotted as crosses ; and it will be seen that a small reduction in the velocity of the centre of mass would bring the two sets of observations into fair agreement. I should add that Mr. Newall's computation of the probable orbit, as given in his paper published in *Monthly Notices* for 1899 November, also gives a period of 104 days.

The last spectroscopic binary to which time will permit me to refer in any detail is *Polaris*, a star the motion of which is marked by some very special features. Between 1896 Septem-



ber 8 and December 8 six spectrograms of *Polaris* were obtained by Campbell, and these gave very consistent results, the mean

radial velocity deduced being one of −19·6 kilometres per second. In 1899 August, however, another spectrograph gave a velocity of −13·1 kilometres per second, and this led to a further series of observations being made, with the result that between 1899 August 9 and 30 velocities varying from −8·6 to −15·2 kilometres per second were obtained. On plotting these results it was clearly indicated—as shown by the diagram on page 254—that *Polaris* was a binary with a period of rather less than four days. The diagram also shows the 1896 results, and the discrepancy between these and the observations of 1899 remained to be explained. Since 1899 *Polaris* has been regularly observed spectroscopically at Mount Hamilton, and the results of these observations are given in the table subjoined, which also includes the results of 1896 and 1899.

Observations of Polaris at the Lick Observatory.

Date.	Velocities in the Line of Sight at Positions of Minima. Kilometres per Second.
1896·9	−20·67
1899·8	−14·22
1900·6	−14·64
1901·4	−16·32
1902·6	−16·79
1903·0	−17·18
1903·7	−17·84
1904·5	−18·52

Professor Campbell's deduction from his observations is that *Polaris* is a triple system, the rapid pair having a period of 3 days 23 hours 14 minutes, and that the velocity of the centre of mass of this pair is changing along a velocity curve corresponding to a period of at least eleven years, but which may be considerably longer. It is evident that some years must still elapse before any really definite determination of this longer period can be arrived at, but meanwhile the progress of the observations at Mount Hamilton will be followed with the greatest interest.

By the year 1901 our Medallist had accumulated enough data relating to radial velocities to justify him in utilising his results for a first rough determination of the Sun's way. For this purpose he used the motions of 280 stars, and these he divided into eighty groups, the mean of the velocities of the stars forming a group being taken as the velocity of that group. Equations of condition were obtained for the eighty groups, each equation being weighted in proportion to the number of stars contained in the group to which it referred, and the eighty equations were then combined and solved by the method of least

squares. The position thus obtained for the apex of the Sun's way was R.A. 277° 30′ and declination +19° 58′, while the Sun's velocity was 19·89 kilometres per second. The right ascension thus found agrees exactly with Newcomb's, and differs only $1\frac{1}{2}$° from Kapteyn's, but in the value of the declination there is a material divergence, Newcomb's declination being 15° and Kapteyn's 14° greater. This result is attributed by Campbell to the extremely unsymmetrical disposition of the groups of stars used in his determination, there being a great dearth of Southern stars—a deficiency which gave rise to the Mills Expedition to Santiago. The organisation of this expedition may well be cited as a splendid example of the thoroughness and vigour with which our Medallist attacked an important problem. Notwithstanding its admitted preliminary character, this determination of the Sun's way by Campbell is of great interest ; and we must all hope that as soon as suitable data have accumulated the work may again be taken in hand by our Medallist. It may be mentioned, by the way, that only last month Mr. H. D. Curtis left Mount Hamilton with his family, to carry on another five years' work in Chile.

The investigation of the solar motion to which I have just referred brought out some interesting facts which I may mention here. One of these was that the average velocity of the stars dealt with was 26·78 kilometres per second in a plane at right angles to the line of sight, while *in space* the average velocity was 34·10 kilometres per second. The deduced velocity for the Sun—namely, 19·9 kilometres per second—was therefore very much smaller than that of the average star of the system.

Another interesting deduction, drawn by our Medallist, concerned the relation between velocity in space and the visual brightness of the stars used in this investigation. Dividing these stars into three groups, of which the first consisted of stars of the third magnitude or brighter, the second of the stars between 3·1 and 4·0 magnitude, and the third of stars fainter than magnitude 4·0, Campbell obtained for the average velocities of the stars in these groups the figures 26·1, 32·3, and 38·88 kilometres per second respectively. This result, which Campbell considers to be in no way due to probable errors of observation, is a very important one, affecting as it does our ideas as to the relation between the proper motion and distance of stars, and it well deserves further examination.

I have devoted considerable time to remarks on the observation of spectroscopic binaries, and the determination of stellar velocities in the line of sight, because these are branches of work with the development of which Campbell has been so prominently and so honourably associated ; but our Medallist has many other strong claims for recognition at our hands, and to some of these I must proceed to direct attention.

During the latter part of 1893 and the first half of 1894 Campbell devoted much time to a thorough examination of such

stars of the Wolf-Rayet type as were observable at Mount Hamilton. The immediate object of the work was to determine whether there was any analogy between these stars and the new star in *Auriga*, and it resulted in the discovery of many points of interest. It would be impossible in this Address to deal with these matters in any detail, but a few features may be mentioned. One point—at that time novel, but since well established—which came out strongly was the great variety of form and intensity assumed in these spectra by lines belonging to the same element. This was particularly the case with the hydrogen lines, which were found some dark and some bright, in different parts of the same spectrum : the dark hydrogen lines in some cases having bright borders, as if doubly reversed, while the bright lines varied from monochromatic lines to broad bands, being in some instances clearly single, and in others apparently multiple. Campbell's observations of spectra, including both dark and bright hydrogen lines, led him to the conclusion that in stars giving such spectra the bright lines are, as a rule, those of greater wave length, and the dark lines those of shorter wave length. Schuster has recently given theoretical grounds for accepting this as possible. Another conclusion is, that the intensities of the bright lines decrease, and those of the dark lines increase, towards the violet end of the spectrum.

Another interesting result was the discovery of a star surrounded by an envelope of hydrogen. This star—which was discovered at Harvard in the course of the Draper Memorial Surveys—is D.M. 30°, 3639, and is of below the 10th magnitude. It nevertheless yields a spectrum which is easily observable on account of the sharpness of its lines, of which 30 were measured by our Medallist in 1893, some of them appearing to be individual to this particular star. The great feature of interest was the behaviour of the Hβ line. To quote Campbell's own words : "When the spectroscope was adjusted for the various parts of the spectrum the line at λ 5694 appeared essentially as a stellar point ; the band at λ 4652 was broad but short, and lay wholly upon the continuous spectrum ; but the line Hβ was narrow and long, extending a very appreciable distance on each side of the continuous spectrum. When the slit was opened wide the Hβ line became a circular disc, while the line λ 5694 and the band λ 4652 remained unchanged." The diameter of this disc was subsequently measured by the micrometer, and found to be about 5″. Campbell's observations of this star were confirmed by Runge in 1897, and by Keeler in 1898. Other stars of similar type have been examined for discs, but, so far as I am aware, this star remains up to the present a unique example of its class.

In connection with the variable behaviour of hydrogen lines, reference may be made here to the interesting observations of *Mira*, carried out by Campbell during the very favourable maximum of 1898. This star, as is well known, has a dark line

spectrum of Secchi's third type with bright hydrogen lines Hγ, Hδ, Hζ, Hη, &c., and it was first examined with the Mills Spectrograph solely for the purpose of determining its velocity in the line of sight. Observations were made in 1897 and 1898, and measures of the dark line spectrum gave a fairly constant velocity of recession of 62·5 kilometres per second. But a comparison of the dark line with the bright line spectrum showed unmistakably that the latter is displaced towards the violet with reference to the former. Owing to the great brilliancy of the Hγ band, it was over-exposed on a number of the plates taken; but on 1898 August 29 a short exposure was made which enabled the structure of the band to be analysed. It was then found to be triple, being composed of three lines of which the central one was by far the strongest, that on the violet side having an intensity of about one-half, and that on the red side of about one-fourth, the intensity of the central line. The mean wave lengths determined for the three components were 4340·24, 4340·60, and 4340·91 respectively. Shortly afterwards Mr. Wright obtained photographs of the Hδ band, and this proved to be also triple, the central line being much the strongest, and the other two about equal to each other in intensity. This band was also displaced towards the violet as compared with the dark line spectrum, and in the case of the component next the red the amount of the displacement agreed closely with that of the corresponding component of the Hγ line; but in the case of the two other components the displacement was considerably greater. About two months later further photographs were obtained of the Hγ and the Hδ bands, when it was found that their character had changed, they being then apparently single lines; moreover the former had materially shifted its position, its wave length being determined as 4340·37; while on the other hand the single Hδ line retained a position practically identical with that of the central component of the triple group observed at the earlier date. So far as the evidence at present available enables us to judge, this tripling of the bright hydrogen lines appears to only take place in the spectrum of *Mira* on the occasion of an exceptionally bright maximum, but it is to be hoped that further evidence on the point may be obtained. As to the cause of the change no explanation is as yet forthcoming, but Campbell is careful to point out that the shifting of the bright lines relatively to the dark line spectrum is not necessarily to be attributed to high velocities of incandescent hydrogen in the line of sight, but that it may be due to change of pressure or other physical causes. In any case the observations are of high interest. I may add that a visual examination of the spectrum of *Mira* by Professor Keeler, Professor Campbell, and Mr. Wright failed to show either Hα or Hβ as bright lines. Professor Campbell noted, however, that as the continuous spectrum became fainter other bright lines appeared, and two of these were apparently iron lines, and showed a displacement

towards the violet agreeing with that of the single Hγ and Hδ lines.

I have, so far, dwelt almost entirely on our Medallist's work in connection with the spectroscopic examination of stellar objects ; but, even at the risk of unduly extending this Address, it is desirable that I should also say at least a few words regarding his valuable contributions to other branches of spectroscopic research. On the occasion of the solar eclipse observed in India, in 1898 January, Campbell included in his programme an attempt to determine the law of rotation of the corona, by measurements of its velocity in the line of sight on opposite sides of the Sun's disc. On account of the high dispersion which it was necessary to employ, our Medallist concluded that it would be hopeless to attempt to deal with any other than the bright line portion of the coronal spectrum, and he determined, therefore, to base his observations on the green line, and not to reject the evidence afforded by even the lowest part of the corona. He further decided, after making some experiments, to employ a prism train in preference to a grating. The prism train used consisted of four compound and two single prisms, giving a combined deviation of 265° 41′.

By a highly ingenious series of shutters he was enabled to get a photographic record of the bright green line in the corona spectrum side by side with portions of the solar spectrum on the same photographic plate, and measurements showed a relative velocity in the line of sight for the east and west sides of the corona of 6·2 kilometres per second, corresponding to a rotational velocity of 3·1 kilometres per second. Campbell, however, regarded this result as subject to a possible error of ±2 kilometres per second, partly owing to errors of observation, but chiefly owing to the character of the bright line itself, the inner ends being over-exposed and the outer ends under-exposed. Thus, while the results of the attempts to determine spectroscopically, during the eclipse of 1898, the rotational speed of the corona were not so definite as could be wished, they were eminently suggestive, and will, it may be hoped, form the foundation for further work in this direction hereafter.

Our Medallist was among those who were successful in adopting the method of employing a moving photographic plate to record the succession of phenomena during a solar eclipse ; and for use during the Indian eclipse of 1898 he devised an instrument which enabled him to take successively on the same plate photographs of the spectrum of the disappearing crescent, of the corona and of the reappearing crescent. This instrument had a Rowland grating placed about 5 inches in front of a camera objective of $2\frac{5}{32}$ inches aperture and $20\frac{3}{4}$ inches focal length ; and the whole of the arrangements for controlling the exposures were characterised by great ingenuity and completeness.

The first and third exposures thus made yielded results of

high interest. The transition from dark to bright lines was indicated by the first exposure very definitely, and it was shown that before the continuous spectrum ceased recording some of the dark lines apparently disappeared. In other cases the dark lines and their corresponding bright lines coexisted until the continuous spectrum ceased to form a sufficiently bright background for the dark lines. Marked anomalies were also shown in the relative intensities of different portions of the dark and bright line spectra, but on these and many other points it is impossible for me to speak on the present occasion, and I will only refer to one other feature of the first exposure which appears to be especially worthy of note. Our Medallist found that in many—but not in all—cases, where dark and bright lines coexisted, the dark lines were displaced towards the violet by as much as four- or five-tenths of a tenth-metre : this effect, however, being almost wholly confined to the first exposure, and at the time of second contact. Campbell has shown strong reasons for believing that this result is not due to any instrumental defect ; while, moreover, another negative (somewhat under-exposed, unfortunately) obtained on a moving plate with another instrument—a collimating spectrograph with a radial slit—showed the same effect for $H\gamma$ and $H\delta$ lines at both second and third contacts. Concerning the meaning of this effect Campbell says : "Assuming the reality of the displacement, we naturally consider its significance from the point of view of wave length. If this is a pressure effect, we conclude that the predominating absorption stratum for these lines is above the predominating radiation stratum. Whether this effect is general over the Sun's surface, or is purely local and confined to certain lines, is immaterial so far as the interpretation of these particular observations is concerned, provided that the pressure in the solar atmosphere increases towards the Sun's centre."

I have referred especially to Professor Campbell's work in connection with the Indian eclipse of 1898, but it must be remembered that the Indian expedition of that year is only one of many such expeditions which have had the benefit of his experience and enthusiasm. It is, in fact, impossible to overrate the importance of the influence which our Medallist has exercised on the eclipse expeditions which have during recent years been sent out from the Lick Observatory ; and probably only those who have taken part in such expeditions can fully appreciate his powers of organisation, and his skill and resourcefulness in devising special lines of research and instrumental means for rendering such researches practicable.

Although I have touched upon so many instances of important work carried out by our Medallist it would be easy, did time permit, to treat of numerous other claims which he has created to recognition at our hands. Amongst these, for instance, are his researches on the spectra of nebulæ, including the comparison of the visual hydrogen spectra of the *Orion* nebula and of a

Geissler tube ; his determinations—as a check on his stellar measurements—of the radial velocities of the Moon and of planets ; his important work on the orbit and parallax of *Sirius* ; his observations on the spectra of comets ; and lastly, but by no means least, his most valuable investigations of the spectroscopic characteristics of temporary stars. Speaking of these latter researches, the Commissioners of the Académie des Sciences, MM. Lœwy, Callandreau, Wolf, Radau, Janssen and Deslandres, who in 1903 awarded to Professor Campbell the Lalande prize, said : "To him we owe the most thorough study of the numerous remarkable temporary stars of recent years ; he has been able to follow to the last stages of their decline the most difficult of observation, and to recognise their more or less complete transformation into nebulæ." These observations would in themselves afford ample scope for lengthy comment, but I am compelled to pass them by with this mere mention. And now, in bringing this Address to a close, I can only express the hope that, incomplete as my record of our Medallist's work has been, it may yet suffice to indicate how greatly our science is indebted to him for important advances secured by researches most excellently planned, and carried out with a skill, persistence, and energy which command our highest admiration. That our Medallist may long be spared to continue the work he has so keenly at heart is our most earnest wish.

It is a matter of regret to us all that it has not been possible for Professor Campbell to be with us this afternoon to receive in person the medal which has been awarded to him. But in view of the fact that it is only a few months since he visited Europe, and of the important work which he has in hand at Mount Hamilton, Professor Campbell's absence, although, as I have said, a matter for regret, is not one for surprise. Moreover, we are not without a compensation. It has on many occasions been our pleasure to heartily welcome in this room Mr. Choate, for so many years the American Ambassador in this country ; and now Professor Campbell's absence has afforded us the opportunity of extending an equally cordial welcome to Mr. Whitelaw Reid, who has succeeded Mr. Choate in his most important office, and who will, I am sure, also succeed him in the esteem and regard of the British nation.

There is a special fitness in Mr. Reid's presence here to-day, as I have learned that—by a peculiarly happy coincidence—he is the son-in-law of Mr. D. O. Mills, through whose munificence it was rendered possible not only to construct the Mills Spectrograph but also to organise and carry out those observing expeditions to Chile which have proved such an extremely valuable aid to Professor Campbell's scheme of research.

Mr. Reid, in handing you this medal which you have kindly undertaken to transmit to Professor Campbell I will ask you to

assure him of the very deep interest which we in England take in the important work which he is so successfully prosecuting, and to express to him our high appreciation of the influence which his researches have exerted—and still are exerting—on the development of astronomical knowledge.

The Meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected :—

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